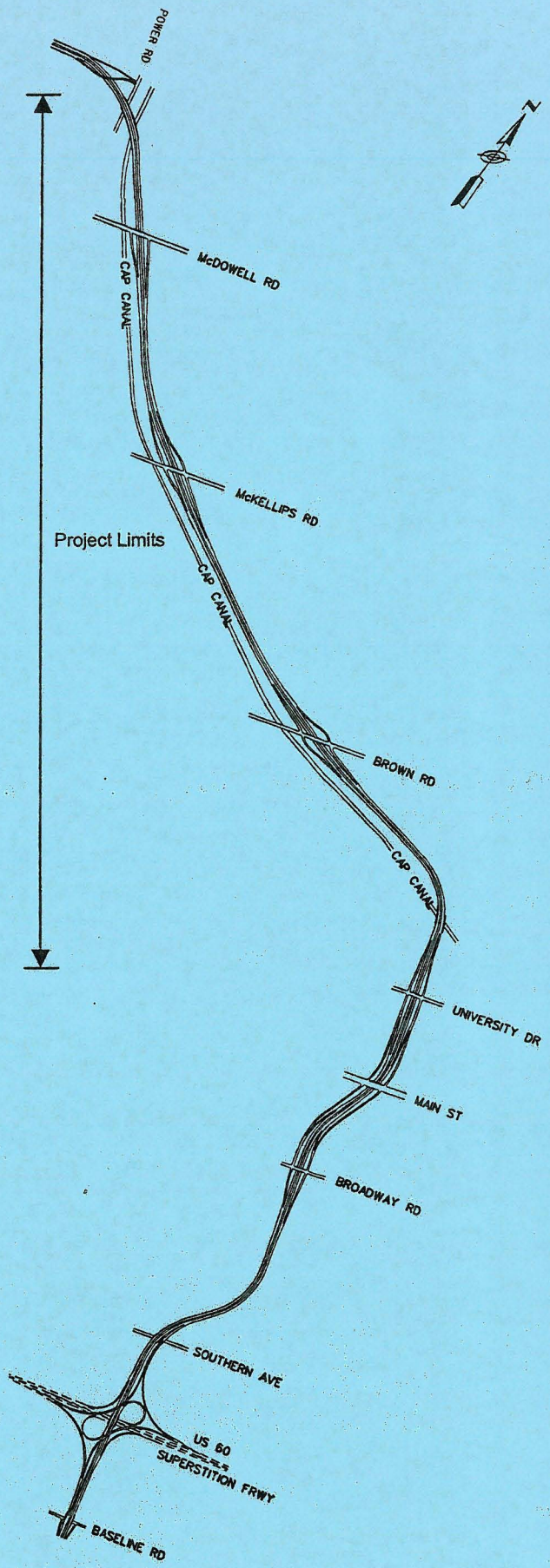
# RED MOUNTAIN FREEWAY (202L)

# POWER ROAD TO UNIVERSITY DRIVE

## SPOOK HILL FLOODWATER RETARDING STRUCTURE

## TECHNICAL REPORT NO. 1 (Final)

## EXISTING CONDITION HYDROLOGY




**Prepared for**

**Arizona Department of Transportation**

**Prepared by**


**DMJM+HARRIS**
**2777 East Camelback Road, Suite 200**
**Phoenix, Arizona 85016**
**(602) 337-2777**


**October 2001**

# RED MOUNTAIN FREEWAY (202L)

# POWER ROAD TO UNIVERSITY DRIVE

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

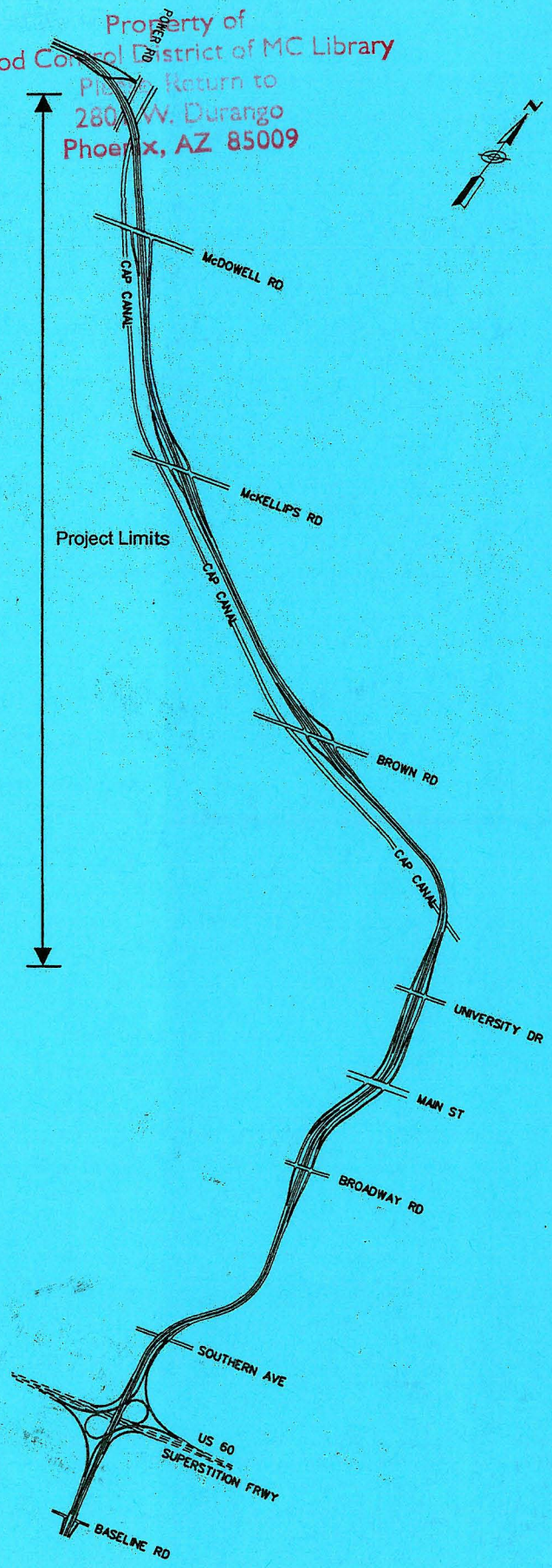
## SPOOK HILL FLOODWATER RETARDING STRUCTURE

## TECHNICAL REPORT NO. 1
## (Final)

## EXISTING CONDITION HYDROLOGY

Registered Professional Engineer (Civil)
CERTIFICATE NO. 32343
I. KAAN TUNCOK
Date Signed 10-25-01
ARIZONA, U.S.A.

Registered Professional Engineer (Civil)
CERTIFICATE NO. 24999
JEFFREY R. MINCH
DATE SIGNED 10-25-01
ARIZONA, U.S.A.




**Prepared for**

**Arizona Department of Transportation**

**Prepared by**

**DMJM+HARRIS**
**2777 East Camelback Road, Suite 200**
**Phoenix, Arizona 85016**
**(602) 337-2777**

**October 2001**

# TABLE OF CONTENTS

**1.0 INTRODUCTION ..... 1**

1.1 PROJECT BACKGROUND ..... 1
1.2 PREVIOUS FREEWAY TECHNICAL AND ENVIRONMENTAL STUDIES ..... 5
1.3 FINAL ENVIRONMENTAL IMPACT STATEMENT (FEIS) MITIGATION MEASURES ..... 7
1.4 STUDY PURPOSE ..... 8
1.5 PREVIOUS HYDROLOGIC STUDIES ..... 9
Evaluation of Preliminary Design Report ..... 10
Final Design Report ..... 10
Phase I Inspection Report ..... 10
1.6 CURRENT STUDIES ..... 11
Spook Hill Area Drainage Master Plan Update ..... 11
FCDMC Structures Assessment Program ..... 11

**2.0 ORIGINAL SPOOK HILL FRS HYDROLOGIC DESIGN ..... 13**

2.1 HYDROLOGIC METHODOLOGY ..... 13
2.2 DESIGN RAINFALL ..... 13
2.3 DESIGN STORM DISTRIBUTIONS ..... 14
2.4 PHYSICAL SUBBASIN CHARACTERISTICS ..... 14
2.5 SOIL CLASSIFICATIONS ..... 15
2.6 LAND USE ..... 15
2.7 RAINFALL LOSS METHODOLOGY ..... 15
2.8 RAINFALL EXCESS TO RUNOFF TRANSFORMATION ..... 16
Time of Concentration ..... 16
Time Lag ..... 16
2.9 BASE FLOW ..... 17
2.10 ROUTING PARAMETERS ..... 17
Channel Routing ..... 17
Reservoir Routing ..... 18
2.11 HYDROLOGY SUMMARY ..... 18

**3.0 STRUCTURE DESIGN ELEVATIONS ..... 19**

3.1 DAM EMBANKMENT ..... 19
3.2 PRINCIPAL SPILLWAY ..... 19
3.3 EMERGENCY SPILLWAY ..... 19
3.4 SUMMARY OF CRITICAL STRUCTURE ELEVATIONS ..... 19
3.5 CROSSROADS ..... 20

**4.0 PROBABLE MAXIMUM FLOOD HYDROLOGIC ANALYSIS ..... 21**

4.1 DRAINAGE AREA BOUNDARIES ..... 21
4.2 SUBBASIN PHYSICAL CHARACTERISTICS ..... 22
4.3 RAINFALL PARAMETERS ..... 23
4.4 SOILS ..... 23
4.5 LAND USE ..... 23
4.6 RAINFALL LOSS PARAMETERS ..... 24
4.7 RAINFALL EXCESS TO RUNOFF TRANSFORMATION ..... 25
Time of Concentration ..... 26
Storage Coefficient ..... 26
Time Area Relation ..... 26
4.8 HYDROLOGIC ROUTING ..... 27
Channel Routing ..... 27
Reservoir Routing ..... 29
4.9 SIGNAL BUTTE INFLOW HYDROGRAPH ..... 29
4.10 LOCAL STORM VS. GENERAL STORM PMF ..... 30
4.11 RESULTS ..... 30

**5.0 SUMMARY ..... 32**

**REFERENCES ..... 33**

## LIST OF FIGURES

FIGURE 1 - MAG REGIONAL FREEWAY SYSTEM ..... 2
FIGURE 2 - PROJECT VICINITY MAP ..... 3
FIGURE 3 - CONCEPTUAL FREEWAY SECTION AT THE SPOOK HILL FRS ..... 4
FIGURE 4 - RED MOUNTAIN FREEWAY FEIS ALTERNATIVE ALIGNMENTS ..... 6

# LIST OF TABLES

TABLE 1 - FRS DESIGN HYDROGRAPHS ..... 13
TABLE 2 - SCS LOCAL STORM PROBABLE MAXIMUM PRECIPITATION ..... 13
TABLE 3 - SCS ADDITIONAL DESIGN STORM PRECIPITATION DEPTHS ..... 14
TABLE 4 - SCS SUBBASIN PHYSICAL CHARACTERISTICS ..... 15
TABLE 5 - SCS CURVE NUMBERS ..... 16
TABLE 6 - TIME OF CONCENTRATION AND TIME LAG - SCS METHODOLOGY ..... 17
TABLE 7 - FINAL DESIGN PEAK FLOWS AND VOLUMES ..... 18
TABLE 8 - CRITICAL STRUCTURE ELEVATIONS ..... 19
TABLE 9 - CROSSROAD DESIGN PEAK INFLOWS ..... 20
TABLE 10 - SPOOK HILL WATERSHED BOUNDARIES ..... 22
TABLE 11 - SUBBASIN PHYSICAL PARAMETERS ..... 22
TABLE 12 - PMP GENERAL STORM ..... 23
TABLE 13 - PMP LOCAL STORM ..... 23
TABLE 14 - LAND USE HYDROLOGIC VARIABLES ..... 24
TABLE 15 - GREEN AND AMPT INFILTRATION PARAMETERS ..... 25
TABLE 16 - CLARK UNIT HYDROGRAPH PARAMETERS ..... 27
TABLE 17 - SYNTHETIC DIMENSIONLESS TIME-AREA VALUES ..... 27
TABLE 18 - NORMAL DEPTH ROUTING PARAMETERS ..... 28
TABLE 19 - NORMAL DEPTH ROUTING MANNING'S ROUGHNESS COEFFICIENTS ..... 28
TABLE 20 - COMPARISON OF GENERAL AND LOCAL STORMS ..... 30
TABLE 21 - DESIGN PEAK DISCHARGES ..... 30
TABLE 22 - HYDROLOGIC SUMMARY ..... 32

# LIST OF PLATES

PLATE 1 - SCS SUBBASIN BOUNDARY MAP
PLATE 2 - WPA SUBBASIN BOUNDARY MAP
PLATE 3 - DMJM+HARRIS SUBBASIN BOUNDARY MAP
PLATE 4 - SOILS MAP
PLATE 5 - MARICOPA COUNTY ZONING MAP
PLATE 6 - CITY OF MESA ZONING MAP

Registered Professional Engineer (Civil)
CERTIFICATE NO. 32343
I. KAAN TUNCOK
Date Signed 10/25/01
ARIZONA, U.S.A.

# APPENDICES

APPENDIX A – DEFINITIONS
APPENDIX B – SCS DESIGN DOCUMENTATION
APPENDIX C – SUPPORTING HYDROLOGIC CALCULATIONS
APPENDIX D – WHITE PAPERS
APPENDIX E – HEC-1 MODELS
APPENDIX F – FEIS CORRESPONDENCE

Registered Professional Engineer (Civil)
CERTIFICATE NO. 24999
JEFFREY R. MINCH
DATE SIGNED 10-25-01
ARIZONA, U.S.A.

# 1.0 INTRODUCTION

## 1.1 Project Background

The Red Mountain Freeway (202L) is a major element of the Maricopa Association of Governments (MAG) adopted Regional Freeway System in the East Valley of Maricopa County. This freeway corridor is shown in Figure 1.

The 202L freeway in the project area is planned as a six-lane facility consisting of three general purpose lanes in each direction of travel separated with a 46-foot open median. High occupancy vehicle (HOV) lanes will be added in the future within the median when traffic volumes warrant this improvement. Auxiliary lanes are planned between successive local service interchange entrance and exit ramps.

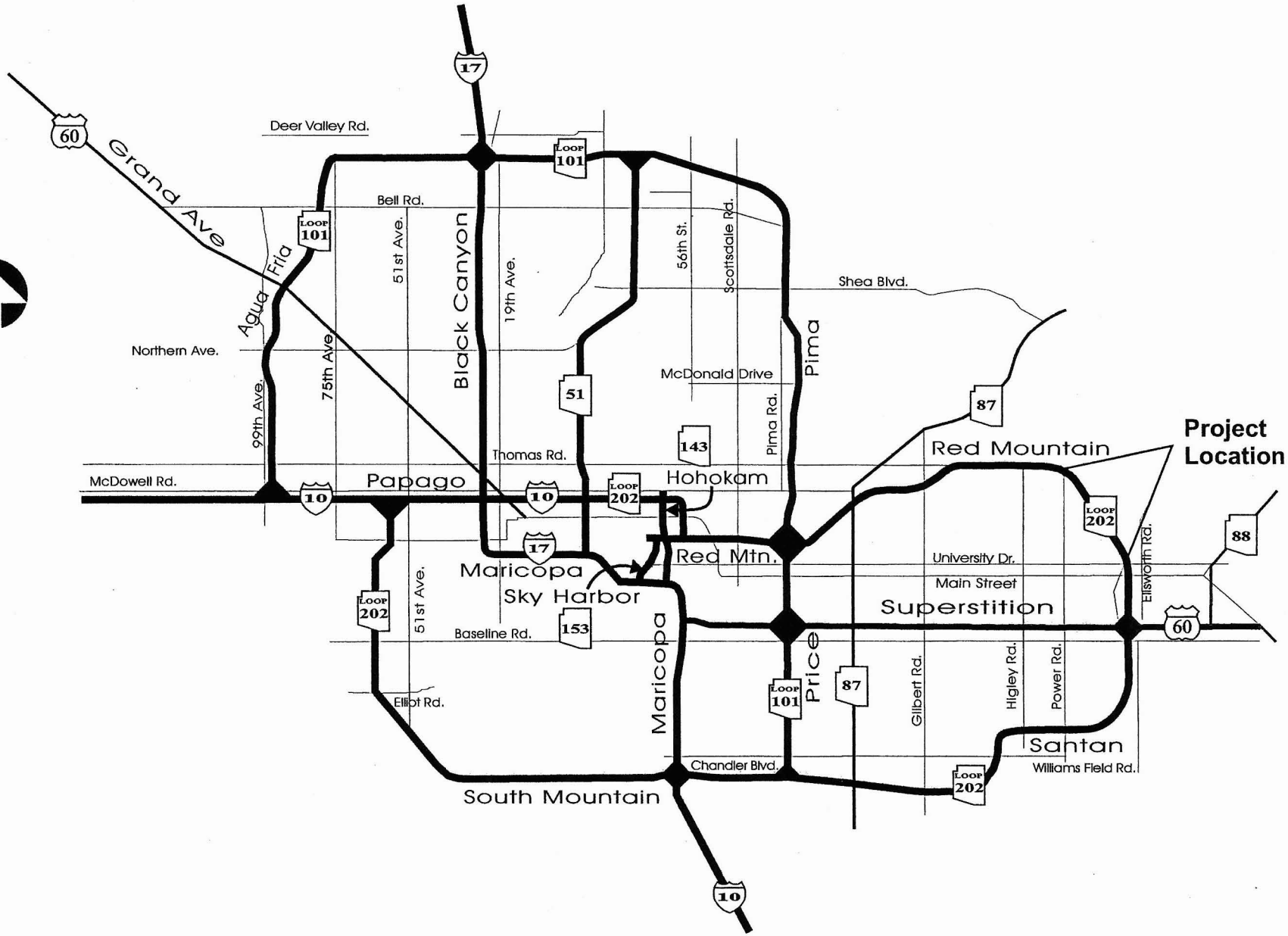
A half diamond traffic interchange is planned for local street access at McDowell Road (south side). Full diamond interchanges are planned at McKellips Road, Brown Road and University Drive. Each local arterial street will cross over the freeway at the interchange location.

Between Power Road and University Drive, the freeway is planned to be located immediately adjacent to the upstream side of the Spook Hill Floodwater Retarding Structure (FRS), within the existing flood reservoir. A Project Vicinity map is provided as Figure 2.

The freeway profile is elevated over Power Road, the Central Arizona Project (CAP) Canal, the Spook Hill FRS, and the Spook Hill FRS emergency spillway. The freeway transitions to an elevation above the 50-year water surface elevation within the FRS. Approximately 5,000 feet southeast of Brown Road, the freeway again passes over the Spook Hill FRS and the CAP Canal. The feasibility of providing a freeway design above the 100-year water surface elevation within the FRS will be investigated with this project.

The conceptual freeway section along the Spook Hill FRS is shown in Figure 3. In addition to the freeway embankment, an earthen berm is planned along the east side of the freeway to provide visual and noise mitigation for the adjacent recreation area and residents.

The freeway embankment volume will be offset with replacement excavation volume obtained within the current flood retention area immediately upstream of the freeway, thereby maintaining the current volume of flood storage. The existing Spook Hill FRS conveyance capacity will also be maintained in accordance with the original design intent.




**MAG REGIONAL FREEWAY SYSTEM**
**RED MOUNTAIN FREEWAY (202L)**
**POWER ROAD TO UNIVERSITY DRIVE**

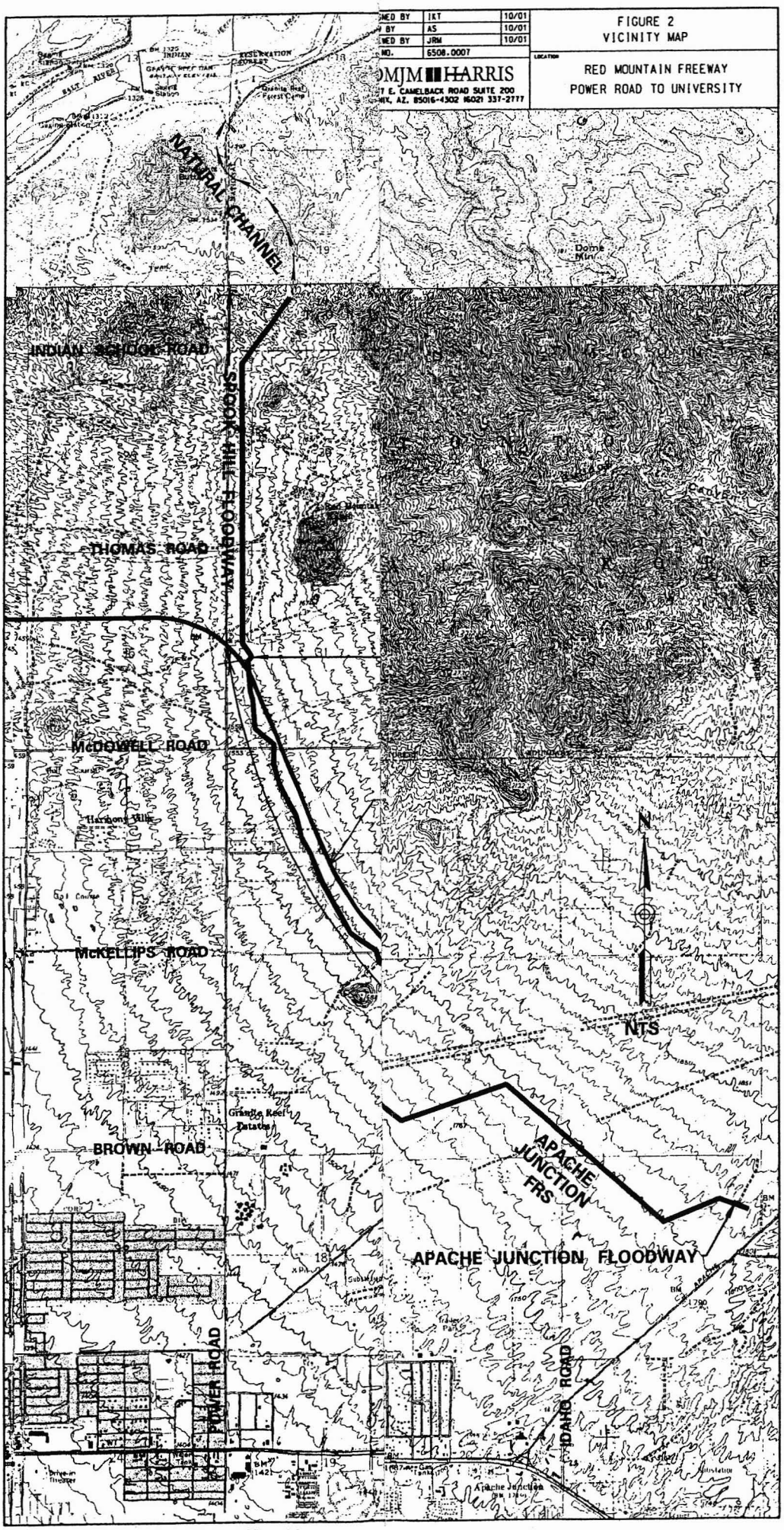
**FIGURE 1**

| | | |
|---|---|---|
| NED BY | IKT | 10/01 |
| BY | AS | 10/01 |
| NED BY | JRM | 10/01 |
| NO. | 6508.0007 | |

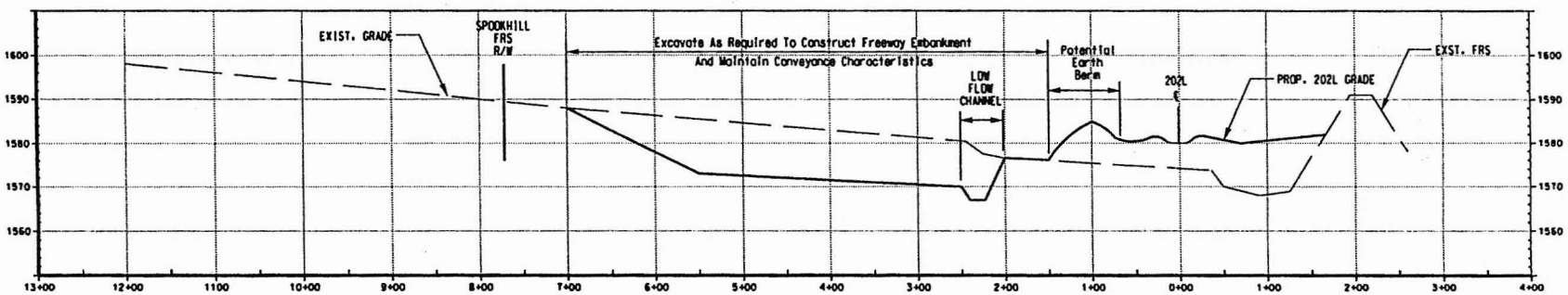
MJM HARRIS
7 E. CAMELBACK ROAD SUITE 200
NIX, AZ. 85016-4302 (602) 337-2777

FIGURE 2
VICINITY MAP

LOCATION
RED MOUNTAIN FREEWAY
POWER ROAD TO UNIVERSITY




J:\rm06\design\drn\hydrology\report\final report\figure 2.dgn




PROPOSED FREEWAY SECTION ADJACENT TO SPOOKHILL FRS

| | | |
|---|---|---|
| DESIGNED BY | IKT | 10/01 |
| DRAWN BY | MAR | 10/01 |
| REVIEWED BY | JRM | 10/01 |
| PROJ NO. | 6508.0007 | |

DMJM HARRIS
2777 E. CAMELBACK ROAD SUITE 200
PHOENIX, AZ. 85016-4302 (602) 337-2777

FIGURE 3
TYPICAL CROSS SECTION

LOCATION
RED MOUNTAIN FREEWAY (202L)

Jk/RM06/Design/Drn/Hydrology/Report/Profiles.dgn

The freeway design concept will require the relocation of portions of the Spook Hill FRS embankment at McDowell Road, McKellips Road and Brown Road. Therefore, coordination will be required with the Flood Control District of Maricopa County (FCDMC), the Arizona Department of Water Resources (ADWR), the National Resource Conservation Service (NRCS), and the City of Mesa.

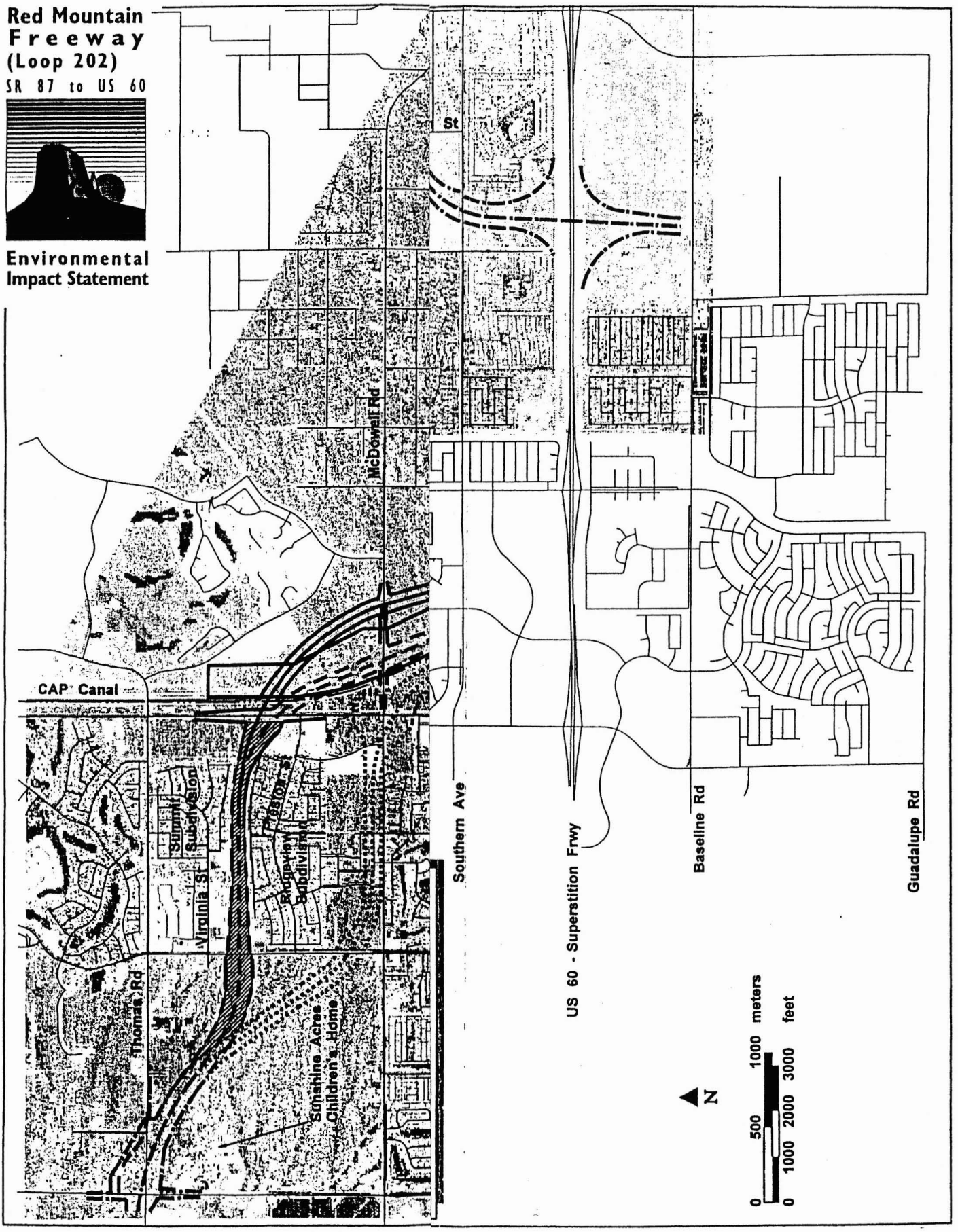
## 1.2 Previous Freeway Technical and Environmental Studies

The Red Mountain Freeway corridor was adopted into the MAG Regional Freeway System in 1985, and was then included in the State Highway System by approval of the State Transportation Board. In 1988, the Arizona Department of Transportation (ADOT) prepared a Design Concept Report for the section of the Red Mountain Freeway between Lindsay Road and Baseline Road. A State-Level Environmental Assessment (EA) was also prepared for this freeway segment. These early design and environmental studies were approved by ADOT and the City of Mesa in 1989, which included the 202L freeway alignment located immediately upstream of the Spook Hill FRS between Power Road and University Drive.

The decisions resulting from the previous corridor studies were reviewed during the completion of the Final Environmental Impact Statement (FEIS) for the Red Mountain Freeway between SR87 (Country Club Drive) and Baseline Road south of US60. With approval by ADOT and the Federal Highway Administration (FHWA) in August 1999, the FEIS finalized the location of the Red Mountain Freeway corridor.

Between Power Road and University Drive, three alignment alternatives were considered during the EIS process (see Figure 4). Two of the alternative alignments avoided the Spook Hill FRS, but encroached into existing and planned development. The public conveyed strong support for the original 1988 alignment alternative along the FRS, and the City of Mesa recommended the selection of the 1988 alignment to be consistent with the Mesa General Plan.

In response to the public and the City of Mesa requests, the alignment selected for the 202L was the original 1988 alignment adjacent to the Spook Hill FRS. The 202L alignment selection was finalized with the approval of the FEIS in August 1999. Agencies supporting the selected alternative included the Flood Control District of Maricopa County (FCDMC), the City of Mesa, and the US Army Corps of Engineers (COE).




Final Environmen AIN FREEWAY FEIS ALTERNATIVE ALIGNMENTS

*Red Mountain F*

*State Route 87*

## 1.3 Final Environmental Impact Statement (FEIS) Mitigation Measures

A partial list of measures recommended to avoid, reduce, or otherwise mitigate environmental impacts associated with the Red Mountain Freeway project is presented below. This partial list relates specifically to the segment of the Red Mountain Freeway adjacent to the Spook Hill FRS. These recommendations will be implemented as part of the project development, right-of-way acquisition, and construction phases of the freeway project. The details of these mitigation measures are referenced to specific sections of the FEIS.

- ADOT will comply with the provisions set forth in Section 402 of the Clean Water Act. ADOT will obtain a NPDES Permit from the EPA and prepare a SWPPP (FEIS, p. 4-67).

- The 100-year floodplain encroachments along the Spook Hill FRS will be mitigated by excavating fill for the freeway from the flood retention basin, thus creating replacement capacity equal to the embankment fill. A new low-flow channel will also be constructed to replace the existing channel, which will be filled by the proposed project (FEIS, p. 4-77, Appendix K).

- If warranted, land will be acquired to be used to restore flood storage and flow carrying capacity of the Spook Hill FRS in accordance with applicable provisions set forth in the ADWR *Rules and Regulations Pertaining to Dam Safety Procedures* [12 Arizona Administrative Code (AAC) 15].

- During the final design of this segment, ADOT will coordinate with the FCDMC to ensure all FCDMC design requirements are adhered to as outlined in the FCDMC letter dated February 23, 1999, and documented in Appendix K of the FEIS. A copy of these letters from the FCDMC and documented in the FEIS is provided in Appendix F of this report.

- ADOT will comply with the general and special conditions of the Section 404 individual permit obtained as part of the FEIS, including compensation for habitat provided by the Spook Hill FRS detention basin and intermittent washes. Compensation (mitigation plan) and permit conditions are presented in Appendix B of the FEIS.

- The Arizona Department of Environmental Quality (ADEQ) has determined that the proposed project is in compliance with ADEQ policies and Section 401 of the Clean Water Act of 1977 (33 U.S.C. 1251). ADOT will comply with the specific conditions of the Section 401 water quality certification included in Appendix B of the FEIS.

- The project will include a series of berms immediately east of the freeway to effectively hide the freeway from view from adjacent recreational areas

through the Red Mountain District Park. These berms will also reduce noise impacts to adjacent recreational and residential areas. ADOT will coordinate the location of these berms to be consistent with the concepts set forth in the Spook Hill District Park Master Plan (FEIS, Appendix B and Appendix F p. 5-47).

## 1.4 Study Purpose

This report is the first in a series of Technical Reports that will be developed by ADOT in support of the design of the Red Mountain Freeway between Power Road and University Drive. These Technical Reports will be developed to address proposed modifications of the Spook Hill FRS in accordance with *ADWR Rules and Regulations Pertaining to Dam Safety Procedures* (12 AAC 15).

ADWR rules apply to projects that reconstruct, repair, alter, enlarge, breach, or remove an existing dam and reservoir. As defined in the Arizona Administrative Code (AAC), "alteration or repair of an existing dam or appurtenant structure" means to change the originally approved construction drawings and specifications or current condition without changing the height or storage capacity of the dam or reservoir, except for ordinary repairs and general maintenance as prescribed in R12-15-1217. Since the FEIS approved concept requires the relocation of the Spook Hill FRS dam embankment at McDowell Road, McKellips Road and Brown Road to accommodate freeway traffic interchanges, the freeway project will require approval from ADWR, the FCDMC (owner of the structure) and other government agencies.

Using the guidelines in Sections R12-15-1203, Exempt Structures, and R12-15-1206, Classification of Dams, the Spook Hill FRS is classified as a small, high hazard jurisdictional dam. Section R12-15-1216, Design of a High, Significant, or Low Hazard Potential Dam makes the following recommendation to establish the inflow design flood requirements:

> "For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from 0.5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions."

The PMF (Probable Maximum Flood) is the flood runoff expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible within a specific region.

The specific purpose of this first Technical Report is to define the existing inflow design flood for the Spook Hill FRS as it relates to the ADWR dam safety rules and regulations. Once the inflow design flood is established, the Red Mountain Freeway hydrologic and hydraulic impacts can be quantified and mitigation measures defined.

As required, subsequent Technical Reports may address the following issues:

- Hydraulics
- Alternatives Evaluation
- Risk Analyses
- Geotechnical Investigations
- Surface Water Diversion Plan
- Dewatering Plan
- Materials Information
- Grout Design
- Reinforced Concrete Design
- Stability Analysis
- Seismicity
- Cutoff Trench Design
- Seepage
- Internal Drainage
- Erosion Protection
- Dam Foundation Design
- Post Construction Vertical and Horizontal Movement Systems
- Foundation Conditions

## 1.5 Previous Hydrologic Studies

The Spook Hill FRS is located in the north central part of the Buckhorn-Mesa watershed in Maricopa County, about 10 miles northeast of downtown Mesa, Arizona. It was designed in 1977 as one element of the Buckhorn-Mesa Public Law 566 Small Watershed Project that was developed by the Soil Conservation Service (SCS). The SCS has recently been renamed the Natural Resource Conservation Service (NRCS).

As shown in Figure 2, the Buckhorn-Mesa project facilities include three floodwater-retarding structures, four floodways, and one diversion structure that were designed to detain a 100-year flood event. The project features include:

- **Apache Junction Dam and Floodway**; includes 1.6 miles of earthen dam and a 1500-foot floodway that diverts floodwater from a wash above the dam into the reservoir area. The structure drains six square miles north of the Town of Apache Junction.

- **Bulldog Floodway**; is 1.7 miles in length and transports stormwater impounded behind the Apache Junction Dam into the reservoir behind the Signal Butte Dam.
- **Pass Mountain Diversion and Outlet**; consists of a 1.2 mile long earth embankment and a 2,800-foot long outlet channel that drains floodwaters from a four square mile area to the Signal Butte Dam.
- **Signal Butte Dam and Floodway**; consists of a 1.3 mile long earthen dam and a 2.7 mile long floodway that conveys floodwaters discharged from the Signal Butte Dam to the Spook Hill Dam. The structure drains 16 square miles above the Apache Trail near the Maricopa - Pinal County boarder.
- **Spook Hill Dam and Floodway.**

**Evaluation of Preliminary Design Report**
This report documents the review of the preliminary design hydrology for the Spook Hill FRS performed by the Portland Section of the SCS, at the request of the Phoenix Section. The computations for determining the required floodwater retarding capacity, principal spillway size, and the emergency spillway crest were found to be satisfactory. The subbasin delineation and TR-20 line diagram developed by the SCS is presented as Plate 1.

**Final Design Report**
This report was finalized by the SCS in 1976 and documents the basis of the hydrologic, hydraulic, structural, foundation and embankment designs for the Spook Hill FRS.

The original TR-20 model was revised to represent a 260-foot wide reinforced concrete drop emergency spillway, instead of a concrete drop combined with an earth auxiliary spillway as recommended by the Evaluation Report. Subbasin delineations and the TR-20 line diagram schematic in this report are the same as the Preliminary Design Report.

**Phase I Inspection Report**
Ertec Western, Inc. (1981) prepared the Inspection Report through a contract with the ADWR, in accordance with the National Dam Inspection Act of 1972. An assessment was performed to verify the structural integrity of the dam and the hydraulic capabilities of the reservoir and outlet facilities to safely pass expected hydrologic events.

The U.S. Army Corps of Engineers (USCOE) HEC-1 Dam Safety computer program (1980) was used for hydrologic and hydraulic evaluations. Computations for the general and local storm Probable Maximum Precipitation (PMP) were also documented in this report.

## 1.6 Current Studies

### Spook Hill Area Drainage Master Plan Update

Wood Patel & Associates, Inc. (WPA) is currently under contract with the Flood Control District of Maricopa County to update the existing Spook Hill Area Drainage Master Plan (ADMP) originally performed in July 1987. The ADMP will quantify the extent of flooding problems, incorporate existing drainage structures into the hydrologic model, and develop alternative solutions to flooding problems for the contributing watershed. The limits of this on-going study are depicted in Plate 2.

The ADMP has two major objectives and one minor objective. The first major objective is to develop a plan to control runoff to prevent flood damage within the watershed. The second major objective is to mitigate the potential increase in runoff due to development in order to preserve the ability of the Buckhorn-Mesa Project to provide protection to lands downstream from future 100-year flood damages. The minor objective is to identify alternatives to minimize risk and liability associated with the FRS structures.

### FCDMC Structures Assessment Program

The FCDMC has initiated a Structures Assessment Program to minimize risk and liability associated with the District's flood control dams. The Structures Assessment Program will be conducted in three phases. Phase I will primarily involve:

- Collection of data and inspection of dams,
- Development of dam safety recommendations and priorities,
- Preliminary alternative analysis studies to modify existing projects to address urbanization related issues, and,
- Evaluation of newly enacted ADWR rule changes and District policy issues.

Phase II will primarily involve:

- Detailed investigations and analyses as identified by need and priority in Phase I,
- Project planning and authorization activities to correct identified distress issues,
- Implementing changes to overall dam safety program and policies, and,
- Conceptual design studies and alternative analyses for modification of projects to address urbanization and distress issues.

Phase III will primarily involve:

- Implementing projects to correct any identified dam safety concerns,
- Implementing approved projects and land acquisitions to address urbanization issues, and,
- Continue the long-term dam safety program.

Kimley-Horn and Associates, Inc. (KHA) completed the Phase I Structures Assessment for the Spook Hill FRS, Signal Butte FRS, and Apache Junction FRS in April 2001. The Phase I Structures Assessment for the Spook Hill FRS included a technical review of available studies and a field examination which developed a list of recommended corrective actions. A summary of further actions/investigations recommended in the Phase I assessment for the Spook Hill FRS is summarized below:

- Monitor longitudinal cracks on the crest of the dam,
- Repair erosion that has occurred on the slopes of the embankment,

- Perform a risk assessment based on breach failure by piping, or piping along a transverse crack,
- Evaluate the need for a transition filter along the longitudinal centerline of the embankment,
- Perform slope stability analyses of the embankment under various loading conditions,
- Perform hydrologic/hydraulic and watershed sediment yield analyses to confirm that the dam provides greater than 100-year flood protection,
- Perform an Incremental Damage Assessment (IDA) assuming failure of the structure versus no structure,
- Prepare a utility database for the structure identifying measures used to control piping and seepage.

The overall conclusion of the field examination is that the Spook Hill FRS and appurtenant structures are in satisfactory operational condition.

# 2.0 ORIGINAL SPOOK HILL FRS HYDROLOGIC DESIGN

The SCS's hydrologic design of the Spook Hill Dam's three major structural elements: dam embankment, spillways and crossroads were developed using the methodology summarized below. Details of the hydrologic methods are documented in the Evaluation of Preliminary Design and Final Design Reports. Pertinent segments of these reports are provided in Appendix B for reference.

## 2.1 Hydrologic Methodology

The SCS hydrologically designed the Spookhill FRS using methods defined in the National Engineering Handbook No. 4, Hydrology [NEH 4, (1972)]. During the design process for the structure, the SCS developed the principal spillway, emergency spillway and freeboard hydrographs. The purpose of these design hydrographs is defined in Table 1.

**Table 1 - FRS Design Hydrographs**

| FRS Structure Element | Design Hydrograph | Design Feature | Design Storm |
|---|---|---|---|
| Dam Embankment | Freeboard | Crest Elevation | PMF[1] |
| Emergency Spillway | Principal Spillway | Crest Elevation | 100-year |
| Emergency Spillway | Freeboard | Spillway Dimensions | PMF |
| Emergency Spillway | Emergency Spillway | Outlet Channel | N.A.[2] |
| Principal Spillway | Principal Spillway | Crest Elevation | 100-year[3] |
| Crossroads | Principal Spillway | Cross-Culvert Size | 10-year |

[1] Probable Maximum Flood (PMF)
[2] Not applicable to design storm frequency
[3] Supporting documentation could not be located

## 2.2 Design Rainfall

The Probable Maximum Precipitation (PMP) is the greatest depth of precipitation for a given duration that is theoretically possible over a particular size storm area at a particular geographical location at a particular time. The PMP presented in Table 2 are based on procedures and guidelines provided in "Probable Maximum Thunderstorm Precipitation Estimates Southwest States". A copy of these calculations is provided in Appendix B.

**Table 2 - SCS Local Storm Probable Maximum Precipitation**

| Rainfall Duration (hrs.) | 1/4 | 1/2 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| Rainfall Depth (in.) | 5.9 | 7.5 | 9.0 | 10.7 | 11.5 | 12.2 | 12.6 | 13.0 |

The precipitation depth for the Emergency Spillway Hydrograph (ESH) was established using the following equation:

$$P = P_{100} + 0.26\ (PMP - P_{100}) = 5.67 \text{ inches}$$

Where:

$P_{100}$ = 100-year, 6-hour precipitation = 3.1 inches
PMP = 13.0 inches

Additional precipitation data documented in the SCS reports is presented in Table 3.

**Table 3 - SCS Additional Design Storm Precipitation Depths**

| Structure | Design Storm Frequency | Point Precipitation (inches) | | Areal Reduction | | Areal Precipitation (inches) | |
|---|---|---|---|---|---|---|---|
| | | 1-day | 10-day | 1-day | 10-day | 1-day | 10-day |
| Emergency Spillway Crest | 100-year | 3.90 | 6.10 | 0.978 | 0.995 | 3.81 | 6.07 |
| Crossroads | 10-year | 2.33 | 3.73 | 0.978 | 0.991 | 2.28 | 3.70 |

## 2.3 Design Storm Distributions

The design rainfall distributions for the principal spillway and emergency spillway hydrographs are presented in NEH 4. The TR-20 computer program provides four options for the cumulative rainfall distribution. SCS used the distribution with dimensionless rainfall and time increments to compute the emergency spillway and freeboard hydrographs. A dimensionless rainfall amount of 1.0 and time increment of 0.02 were used in computations. Since the rainfall duration is 6 hours, the dimensionless time increment of 0.02 is equal to a time increment of 7.2 minutes. The TR-20 rainfall distribution is presented in Appendix B and Table C.1.

## 2.4 Physical Subbasin Characteristics

U. S. Geological Survey (USGS) 7.5-minute series topographic quadrangle maps were utilized to define the subbasin boundaries. The TR-20 line diagram and drainage area boundaries are provided as Plate 1. The SCS subbasin parameters (i.e., the drainage area, length and average slope) along the Spook Hill FRS, between the FRS inlet and the principal spillway outlet (Subbasins 18-22) and along the Signal Butte Floodway (Subbasins 14-17), are summarized in Table 4.

**Table 4 - SCS Subbasin Physical Characteristics**

| Subbasin No. | Area (sq. mi.) | Drainage Length (ft) | Average Slope (ft/ft) | Remarks |
|---|---|---|---|---|
| 14 | 0.25 | 5,500 | 0.013 | Start Signal Butte Floodway |
| 15 | 0.68 | 5,500 | 0.010 | |
| 16 | 1.22 | 12,200 | 0.020 | |
| 17 | 1.44 | 14,300 | 0.024 | End Signal Butte Floodway |
| 18 | 0.92 | 13,000 | 0.021 | Start Spook Hill FRS |
| 19 | 4.08 | 25,800 | 0.036 | |
| 20 | 1.28 | 15,800 | 0.028 | |
| 21 | 1.91 | 18,000 | 0.038 | |
| 22 | 1.79 | 14,500 | 0.030 | End Spook Hill FRS |

## 2.5 Soil Classifications

The soil types within the study limits were characterized as hydrologic Group B and Group D soils.

Group B soils have moderate infiltration rates when thoroughly wetted and consist mainly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. The U.S. Department of Agriculture (USDA) soil textures normally included in this group are silt loam and loam.

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist mainly of clay soils with a high swelling potential, soils with a permanent high water table, and soils over nearly impervious material. The USDA soil textures normally included in this group are clay loam, silty clay loam, sandy clay, silty clay, and clay. The distribution of these two soil groups within each subbasin is provided in Appendix B.

## 2.6 Land Use

As documented in the SCS studies, the land use at the time in the contributing watershed to the Buckhorn-Mesa structures was identified as either residential (approximately 100-299 homes per square mile) or desert range land. The runoff curve numbers associated with these land uses are presented in Appendix B.

## 2.7 Rainfall Loss Methodology

The SCS runoff Curve Number (CN) method was used for computing abstractions from storm rainfall. The CN values used in the final design for the contributing watershed are provided in Table 5.

**Table 5 - SCS Curve Numbers**

| Subbasin No. | Curve Number |
|---|---|
| 14 | 75 |
| 15 | 75 |
| 16 | 75 |
| 17 | 75 |
| 18 | 75 |
| 19 | 76 |
| 20 | 75 |
| 21 | 76 |
| 22 | 79 |

## 2.8 Rainfall Excess to Runoff Transformation

Precipitation excess was transformed to direct runoff by using SCS unit hydrograph methodology. The required input parameters, time of concentration and time lag, were computed using the following equations:

### Time of Concentration

Time of concentration was computed by using the following equation:

$$T_c = L / V$$

Where:

$T_c$ = time of concentration (seconds)
L = average drainage length (ft)
V = average velocity (ft/s)

Average velocity was related to the average basin slope as follows:

- If the average slope within the subbasin was greater than 0.02 ft/ft, a velocity of 6 ft/s was assumed, and
- If the average slope within the subbasin was less than 0.02 ft/ft, a velocity of 4 ft/s was assumed.

### Time Lag

Time lag, the lag (hours) between the center of mass of rainfall excess and the peak of the unit hydrograph, was computed by using the standard relationship of Time Lag is equal to 0.6 x $T_c$. The results of their analysis are summarized in Table 6.

**Table 6 - Time of Concentration and Time Lag - SCS Methodology**

| Subbasin No. | Time of Concentration (hrs.) | Time Lag (hrs.) |
|---|---|---|
| 14 | 0.38 | 0.23 |
| 15 | 0.38 | 0.23 |
| 16 | 0.56 | 0.34 |
| 17 | 0.66 | 0.40 |
| 18 | 0.60 | 0.36 |
| 19 | 1.19 | 0.71 |
| 20 | 0.73 | 0.44 |
| 21 | 0.83 | 0.50 |
| 22 | 0.67 | 0.40 |

## 2.9 Base Flow

The inflow hydrograph to the Spook Hill FRS from the Signal Butte Floodway was computed using the following process:

- Use the 100-year flood principal spillway maximum outflow from Signal Butte FRS as base flow to the Signal Butte Floodway,
- Route the 100-year, 24-hour storm down the Signal Butte Floodway from the contributing watershed,
- Increase the resulting inflow hydrograph from the Signal Butte Floodway by 30% to account for the freeboard design capacity of the floodway.

This approach resulted in a peak flow estimate of 2888 cfs at the inlet of the Spook Hill FRS. Supporting documentation is provided in Appendix B.

## 2.10 Routing Parameters

### Channel Routing

The flood hydrograph was routed through floodways using a Modified Attenuation-Kinematic (Modified Att-Kin) method. This procedure is based on the Att-Kin procedure described in TR-66 (1981). Channel routing was not utilized along the flood retarding structures.

For each channel reach, the Att-Kin procedure routes the flood hydrograph through the reach using a mathematical storage model. The procedure then positions the peak in time and distorts the storage-routed hydrograph using the kinematic model. The combined routing is done so the outflow hydrograph satisfies the conservation of mass equation at the time to peak for the outflow hydrograph. A detailed discussion of the Att-Kin procedure is presented in TR-66.

### Reservoir Routing

The inflow flood hydrographs were routed through the Spook Hill FRS reservoir using the Storage-Indication method. The starting water-surface elevation for routing computations was 1,579.01 feet based on the National Geodetic Vertical Datum of 1929 (NGVD 29).

The Storage-Indication method is based on the principles of level pool routing. This procedure is used for calculating the outflow hydrograph from a reservoir with a horizontal water surface, given its inflow hydrograph and storage-outflow characteristics. The details of this methodology are presented in NEH 4. The as-built stage-storage and stage-discharge relationships for the Spook Hill dam and reservoir are presented in Appendix C. The stage-storage function was computed using the USGS quadrangle maps.

## 2.11 Hydrology Summary

SCS developed the peak inflows to the Spook Hill FRS and the Signal Butte Floodway for the PMP using the methodology described above. These design inflows are summarized in Table 7, which were utilized to define the freeboard hydrograph and top of the dam embankment.

**Table 7 - Final Design Peak Flows and Volumes**

| Subbasin No. | Peak Discharge (cfs) | Peak Volume (acre-ft.) |
|---|---|---|
| 14 | 1,590 | 130 |
| 15 | 4,325 | 353 |
| 16 | 6,913 | 632 |
| 17 | 7,610 | 745 |
| 18 | 5,125 | 477 |
| 19 | 15,675 | 2,142 |
| 20 | 6,492 | 662 |
| 21 | 9,124 | 1,002 |
| 22 | 9,945 | 980 |

# 3.0 STRUCTURE DESIGN ELEVATIONS

Using the results of the hydrograph methodologies outlined in the previous section, the SCS defined the Spook Hill FRS structure control elevations and dimensions. A summary of these critical elevations is provided below.

## 3.1 Dam Embankment

The Spook Hill FRS is a compacted zoned earthfill structure with a total length of 21,712 feet. The maximum height of the structure is 23 feet and the width varies from 14 feet at the crest to a maximum of about 125 feet at the base. The embankment crest elevation is 1,591.0 feet (NGVD 29).

## 3.2 Principal Spillway

The principal spillway consists of a drop inlet structure cast into a 7.5 x 7-foot reinforced concrete box culvert through the dam, with a Saint Anthony Falls (SAF) energy dissipator at the outlet. The outlet leads to the Spook Hill floodway, constructed to convey floodwaters northward to a point where the flood waters discharge to a natural wash and ultimately into the Salt River just upstream from the Granite Reef Dam. The uncontrolled overflow elevation of the Principal Spillway intake is 1,577.5 feet (NGVD 29).

## 3.3 Emergency Spillway

The single emergency spillway for the dam is a 260-foot wide Type C, reinforced concrete, straight drop spillway. The crest elevation is 1,582.0 (NGVD 29) and the bottom elevation of the stilling basin is 1,568.0 feet (NGVD 29).

## 3.4 Summary of Critical Structure Elevations

The following conversion factor was developed for the Area Drainage Master Plan (ADMP) Update to convert NGVD 29 elevations to the North American Vertical Datum of 1988 (NAVD 88):

(NGVD 29 Elevation) + 1.86 feet = (NAVD 88 Elevation)

A summary of the critical structure elevations for the Spookhill FRS is provided in Table 8.

**Table 8 - Critical Structure Elevations**

| Structure | NGVD 29 Elevation (ft) | NAVD 88 Elevation (ft) |
|---|---|---|
| Dam Crest | 1,591.00 | 1,592.86 |
| Principal Spillway Intake | 1,577.50 | 1,579.36 |
| Emergency Spillway Crest | 1,582.00 | 1,583.86 |

## 3.5 Crossroads

Principal Spillway Hydrograph (PSH) procedures were used to compute the crossroad elevation and its impact on dam safety. A schematic of the multi-reservoir system between Brown Road and the Principal Spillway, documented in the Evaluation of Preliminary Design Report, is presented in Appendix B. The PSH was developed using one and 10-day precipitation depths for the 10-year flood. A copy of the PSH input parameters documented in the Final Design Report is provided in Appendix B. The original design confirmed that the proposed crossroad profiles did not impact the dam crest elevation when routing the freeboard hydrograph. The peak inflow rates along the multi-reservoir system are summarized in Table 9.

**Table 9 - Crossroad Design Peak Inflows**

| Reservoir No. | Location | Peak Inflow (cfs) |
|---|---|---|
| 1 | North of McDowell Rd. | 106 |
| 2 | McDowell Rd. to McKellips Rd. | 222 |
| 3 | McKellips Rd. to Brown Rd. | 412 |
| 4 | South of Brown Rd. | 306 |

# 4.0 PROBABLE MAXIMUM FLOOD HYDROLOGIC ANALYSIS

Based on ADWR recommendations, the hydrologic methodology presented herein utilizes the procedures and guidelines presented in the Drainage Design Manual for Maricopa County, Volume I, Hydrology (1995). The inflow hydrographs for the Spook Hill FRS presented in this report utilize existing land use conditions based on current zoning for the Probable Maximum Flood (PMF) and selected increments of the PMF.

The agency review comments to the draft Technical Report No. 1 identified a number of issues that required resolution prior to finalizing the existing condition hydrology. The project team decided the best approach to reaching consensus on these issues was to develop a series of white papers addressing each issue individually. DMJM+HARRIS produced a series of three white papers for the following subjects:

- Time of Concentration – A Modification to the TR-55 Methodology,
- Spook Hill FRS – Emergency Spillway Stage-Discharge Curve,
- Spook Hill FRS – Signal Butte Floodway Inflow Hydrograph.

The agencies approved the proposed methodologies and computational process presented in these white papers at a consensus meeting held on August 7, 2001. The white papers are provided in Appendix D in support of the approved methodology for the existing condition hydrologic analyses. The calculations presented with this section of the report supercede the white paper calculations in support of the recommended design hydrologic analyses for the Red Mountain Freeway within the Spook Hill FRS.

## 4.1 Drainage Area Boundaries

The Spook Hill FRS and the Signal Butte Floodway are located on alluvial plains and intermediate slopes of the Usery Mountains and Pass Mountain. As documented in the Inspection Report (1981), topographic features range from gently sloping to moderately sloping near the FRS, to low hills and steep mountains with slopes ranging from 10 to 80 percent. Elevations range from 1,570 feet at the FRS, to over 3,300 feet at the peak of Pass Mountain. The uppermost area in the Usery Mountains is part of the Tonto National Forest administered by the U.S. Forest Service.

USGS 7.5 Minute Series topographic quadrangle maps were utilized to define the subbasin boundaries. The three USGS quadrangle maps used were Apache Junction, Buckhorn, and Granite Reef Dam.

In general, the watershed boundaries and calculated areas match the original final design. Special consideration was given to delineation of subbasins in order to provide design inflow hydrographs at the major crossroads. The guidelines presented in Table 10 were used to delineate the major contributing boundaries to the Spook Hill watershed.

**Table 10 - Spook Hill Watershed Boundaries**

| Boundary | Comments |
|---|---|
| Northern | The boundary is located along the crest of the Usery Mountains. The portion of the Spook Hill watershed south of this boundary drains into the Spook Hill FRS. |
| Eastern | Separates the segment of the watershed that drains to the Pass Mountain Diversion Channel and Signal Butte Floodway from the segment that drains directly into the Spook Hill FRS. |
| Southern/ Western | Separates the segment of the watershed that drains into the Spook Hill Floodway from the segment that drains directly into the Spook Hill FRS. |

Subbasin boundaries were established using internal topographic features in the Spook Hill watershed. Since peak flows will be computed for the PMF event, existing structural features including detention/retention facilities and conveyance channels were not considered in this evaluation.

The entire uncontrolled drainage area between the Pass Mountain Diversion channel and the Signal Butte FRS, upstream of the Spook Hill FRS, was considered when defining the inflow hydrographs along the Signal Butte Floodway.

The proposed design subbasin delineation map is presented as Plate 3.

## 4.2 Subbasin Physical Characteristics

The physical subbasin characteristics were computed using the USGS 7.5-minute series topographic quadrangle maps. These parameters are summarized in Table 11.

**Table 11 - Subbasin Physical Parameters**

| Subbasin No. | Area (sq. mi.) | Drainage Length (ft.) | Average Slope (ft/ft) | Remarks |
|---|---|---|---|---|
| F | 0.15 | 3,970 | 0.016 | Start Signal Butte Floodway |
| G | 0.52 | 4,150 | 0.018 | |
| H | 0.86 | 14,410 | 0.023 | |
| I | 1.32 | 17,088 | 0.025 | End Signal Butte Floodway |
| A1 | 0.96 | 12,277 | 0.036 | Start Spook Hill FRS |
| B1 | 4.09 | 28,939 | 0.054 | |
| B2 | 1.36 | 17,781 | 0.032 | |
| C1 | 2.54 | 18,005 | 0.068 | |
| D1 | 1.15 | 13,902 | 0.065 | End Spook Hill FRS |

The Drainage Design Management System for Windows (DDMSW, 1999) developed by the Flood Control District of Maricopa County was used to facilitate data management and computational procedures required for the physical parameters.

## 4.3 Rainfall Parameters

The inflow design flood hydrographs for the PMF and selected increments of the PMF were computed based on the Probable Maximum Precipitation. Local and general storm PMP rainfall depths were developed by using the procedures and guidelines in the U.S. Army Corps of Engineers Hydrometeorological Report No. 49 [HMR 49 (1977)]. The local storm PMP was distributed utilizing procedures in HMR 49. The general PMP was distributed (72-hour) using guidelines provided by the ADWR (See Appendix C). Computations for the precipitation depth and distribution for both the general and local storms are presented in Tables C.2-C.5. The rainfall depths for these storm events are summarized in Tables 12 and 13.

**Table 12 - PMP General Storm**

| Rainfall Duration (hrs.) | 6 | 12 | 18 | 24 | 48 | 72 |
|---|---|---|---|---|---|---|
| Rainfall Depth (in.) | 10.2 | 12.8 | 14.3 | 15.4 | 18.3 | 19.4 |

**Table 13 - PMP Local Storm**

| Rainfall Duration (hrs.) | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Rainfall Depth (in.) | 9.4 | 10.8 | 11.5 | 12.0 | 12.4 | 12.8 |

## 4.4 Soils

The soil map developed by WPA (see Plate 4) for the Spook Hill ADMP was utilized to quantify the areal distribution of the soil types within each subbasin. The soil properties defined in the Aguila-Carefree Soil Survey were used in DDMSW. The areal distribution of the soil parameters for each subbasin is presented in Table C.6.

## 4.5 Land Use

Maricopa County and City of Mesa zoning maps, presented as Plates 5 and 6, were used to establish the hydrologic parameters associated with different land use types. Major land use characteristics identified for the Spook Hill watershed are Desert, Very Low Density Residential (VLDR), Low Density Residential (LDR), Medium Density Residential (MDR), Multiple Family Residential (MFR), Forest and Mountain.

The land use hydrologic variables presented in Table 14 were used in the hydrologic analysis. The areal distribution of the land uses for each subbasin is presented in Table C.7 in Appendix C.

**Table 14 - Land Use Hydrologic Variables**

| Land Use Type | Vc[1] (%) | RTIMP[2] (%) | DTHETA[3] Condition | IA[4] (inches) |
|---|---|---|---|---|
| Desert | 25 | 0 | Dry | 0.35 |
| VLDR | 20 | 5 | Normal | 0.30 |
| LDR | 50 | 15 | Normal | 0.30 |
| MDR | 50 | 30 | Normal | 0.25 |
| MFR | 50 | 45 | Normal | 0.25 |
| Forest | 90 | 0 | Normal | 0.15 |
| Mountain | 85 | 0 | Normal | 0.50 |

[1] Vegetation cover
[2] Effective impervious area
[3] Volumetric soil moisture deficit
[4] Initial abstraction

## 4.6 Rainfall Loss Parameters

Rainfall infiltration losses were computed using the Green and Ampt methodology, which is an approximate mathematical model utilizing Darcy's law. The original model was developed for ponded infiltration into a deep homogenous soil with a uniform water content. Water is assumed to infiltrate into the soil through a wetting front, which separates the wetted and unwetted zones of the soil.

The Green and Ampt method requires the definition of five parameters for each subbasin: initial abstraction (IA), hydraulic conductivity at natural saturation (XKSAT), wetting front capillary suction (PSIF), volumetric soil moisture deficit at the start of rainfall (DTHETA), and effective impervious area (RTIMP).

Since subbasins within the Spook Hill watershed are composed of several subareas containing soils of different textures, a composite value for the Green and Ampt parameters was determined. The procedure for computing the composite value of XKSAT is defined in the FCDMC Hydrology Manual as:

$$\overline{XKSAT} = ALOG\left(\frac{\sum A_i \log XKSAT_i}{A_T}\right)$$

Where:

$\overline{XKSAT}$ = composite hydraulic conductivity (inches/hr)
$XKSAT_i$ = hydraulic conductivity of a soil type (inches/hr)
$A_i$ = size of subarea ($mi^2$)
$A_T$ = size of the modeling subbasin ($mi^2$)

DDMSW first computes $\overline{XKSAT}$, and then selects values of PSIF and DTHETA (normal or dry) by using the guidelines in the FCDMC Hydrology Manual (1995).

These parameters are estimated based on bare ground conditions. Since the PSIF parameter is insensitive to ground cover in comparison with XKSAT, only the hydraulic conductivity is adjusted for vegetative cover using the following equation:

$$\overline{XKSAT}_{adj} = \left[\frac{V_c - 10}{90} + 1.0\right] \overline{XKSAT}$$

Where:

$V_c$ = Percentage of vegetative cover

The Green and Ampt infiltration parameters within the Spook Hill watershed are summarized in Table 15 on the following page. Example hand computations are provided in Appendix C.

## 4.7 Rainfall Excess to Runoff Transformation

Precipitation excess was transformed to direct runoff using the Clark unit hydrograph. The Clark unit hydrograph method requires the use of three parameters: time of concentration (Tc), storage coefficient (R), and a time area relation.

**Table 15 - Green and Ampt Infiltration Parameters**

| Subbasin No. | PSIF (inches) | DTHETA | XKSAT | IA (inches) | RTIMP (%) |
|---|---|---|---|---|---|
| F | 4.50 | 0.25 | 0.37 | 0.30 | 9 |
| G | 5.70 | 0.25 | 0.24 | 0.30 | 15 |
| H | 4.40 | 0.25 | 0.41 | 0.32 | 14 |
| I | 4.50 | 0.25 | 0.39 | 0.30 | 15 |
| A1 | 4.25 | 0.26 | 0.47 | 0.30 | 16 |
| B1 | 4.45 | 0.25 | 0.41 | 0.29 | 11 |
| B2 | 4.35 | 0.26 | 0.46 | 0.31 | 15 |
| C1 | 4.35 | 0.26 | 0.46 | 0.31 | 15 |
| D1 | 3.64 | 0.27 | 0.67 | 0.30 | 17 |

### Time of Concentration

A new computational procedure was developed for the time of concentration variable. The new methodology combines the procedures and guidelines presented in the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS) Technical Release 55 (TR-55) with a computational algorithm developed by DMJM+HARRIS. Using a unit width approach, the algorithm iteratively defines the average channel flow parameters to determine the channel element travel time and ultimately the time of concentration for the contributing watershed. The details of the computational algorithm are presented in a white paper in Appendix D.

The supporting time of concentration calculations for the hydrologic models presented in this report are provided in Appendix C. For composite urban and rural subbasins, an arithmetic average of the Manning's "n" for each land use was applied. The supporting calculations reevaluated the channel slopes and effective downstream subbasin widths for the final hydrologic analyses. The iterative solution for the final time of concentration converges at 0.01 hours.

### Storage Coefficient

The storage coefficient (R) is computed by using the following equation:

$$R = 0.37\left(T_c^{1.11}\, A^{-0.57}\, L^{0.80}\right)$$

Where:

- R = storage coefficient (hours)
- $T_c$ = time of concentration (hours)
- A = drainage area ($mi^2$)
- L = length of flow path (miles)

Time of concentration ($T_c$) and storage (R) coefficients for the local storm PMP are presented in Table 16 on the next page. The general storm PMP results in larger values of time of concentration.

### Time Area Relation

The dimensionless time area relation, presented in Table 17 on the next page, reflects natural and urban watersheds. The predominant land use was used to define the applicable time area relation for each subbasin. Where mixed urban/natural land uses occur within a specific subbasin, the HEC-1 default time area relation was applied.

**Table 16 - Clark Unit Hydrograph Parameters**

| Subbasin No. | $T_c$ (hrs.) | R |
|---|---|---|
| F | 1.04 | 0.908 |
| G | 1.03 | 0.456 |
| H | 2.03 | 1.977 |
| I | 2.01 | 1.752 |
| A1 | 1.22 | 0.925 |
| B1 | 1.86 | 1.290 |
| B2 | 1.87 | 1.641 |
| C1 | 1.07 | 0.626 |
| D1 | 0.90 | 0.649 |

**Table 17 - Synthetic Dimensionless Time-Area Values**

| Time (percent of $T_c$) | Contributing Area (Percent Total Area) | |
|---|---|---|
| | Urban Watersheds | Natural Watersheds |
| 0 | 0 | 0 |
| 10 | 5 | 3 |
| 20 | 16 | 5 |
| 30 | 30 | 8 |
| 40 | 65 | 12 |
| 50 | 77 | 20 |
| 60 | 84 | 43 |
| 70 | 90 | 75 |
| 80 | 94 | 90 |
| 90 | 97 | 96 |
| 100 | 100 | 100 |

## 4.8 Hydrologic Routing

### Channel Routing

For existing conditions, hydrologic routing processes were utilized to route the inflow hydrographs along the Signal Butte Floodway. These processes are applicable to conditions where the backwater effects are negligible. Therefore, they were not used to route the inflow hydrographs along the Spook Hill FRS.

For existing and proposed conditions, a hydraulic routing model will be developed to route the inflow hydrographs along the Spook Hill FRS. The design of the crossroads will be based on this hydraulic routing process. This type of model is based on partial differential equations (the Saint Venant equation for

one-dimensional flow) that allow the flow rate and water level to be computed as functions of space and time, rather than of time alone as in hydrologic models.

Normal depth routing, a hydrologic routing method, was used to route the inflow hydrographs along the floodway. Since there is no retarding structure along the floodway, runoff volume in excess of the floodway capacity was diverted towards the CAP Canal. Therefore, this excess flow volume was diverted prior to routing the design inflow hydrographs through the floodway. Key parameters used for the normal depth routing include:

- A representative 8-point cross-section: The Signal Butte Floodway as-built plans were used to establish the cross-section dimensions. These dimensions are summarized in Table 18.

**Table 18 - Normal Depth Routing Parameters**

| Channel Type | Floodway Station[1] | | Bottom Width (ft) | Top Width (ft) | Side Slope |
|---|---|---|---|---|---|
| | From | To | | | |
| Trapezoid | 23+00 | 32+00 | 16 | 53.2 | 2:1 |
| Trapezoid | 32+00 | 37+00 | 20 | 57.2 | 2:1 |
| Trapezoid | 37+00 | 70+00 | 20 | 58.8 | 2:1 |
| Trapezoid | 70+00 | 96+73 | 32 | 70.8 | 2:1 |
| Rectangle[2] | 96+73 | 105+25 | 10 | 10 | - |
| Rectangle[3] | 105+25 | 156+50 | 14 | 14 | - |

[1] Signal Butte Floodway stations are based on SCS as-builts.
[2] The depth of this section varies between 6.5 and 7 feet.
[3] The depth of this section averages 7.5 feet.

- Roughness values for channel and overbank areas: A field reconnaissance was performed to establish roughness coefficients for the concrete and earth sections of the Signal Butte Floodway. These roughness coefficients are summarized below in Table 19.

**Table 19 - Normal Depth Routing Manning's Roughness Coefficients**

| Channel Material | Manning's Roughness | | |
|---|---|---|---|
| | Left Overbank | Main Channel | Right Overbank |
| Concrete | 0.016 | 0.016 | 0.016 |
| Earth | 0.035 | 0.025 | 0.035 |

The hydrologic routing of the Signal Butte Floodway was simplified based on slope and channel type for the final Spook Hill FRS hydrologic model.

### Reservoir Routing

The Modified-Puls method, a level-pool reservoir routing procedure, was used to compute the outflow hydrograph from the Spook Hill FRS reservoir. The basic methodology is similar to the Storage-Indication method used in TR-20 and requires the use of an inflow hydrograph and the storage-outflow characteristics of the reservoir.

WPA modified the stage-storage function (see Figure C.3) developed by the SCS (see Figure C.1) for Spook Hill Dam and Reservoir. They modified the stage-storage function to account for differences in available sediment storage capacity based on and detailed mapping. The SCS and WPA used sediment volumes of 200 acre-feet and 271 acre-feet, respectively.

Stage-Storage Function

As defined in the SCS as-builts, 4,070 acre-feet can be stored within the Spook Hill reservoir at an elevation of 1,591.0 feet (top of dam elevation, NGVD 29). SCS developed this stage-storage function using maps that were available during the development of the Final Design Report.

In order to increase the accuracy of the stage-storage function, WPA used a recent 2-foot contour interval map of the Spook Hill dam and reservoir. A comparison of this function to the one developed by the SCS is provided as Figure C.6 in Appendix C.

The function developed by WPA was used as the basis of the existing condition hydrology model developed in this report. As shown in Appendix C, Figure C.4, WPA's stage-storage function was modified by extending it up to the volume of 5,100 acre-feet, using the SCS stage-storage function. A comparison to the SCS stage-storage function is also presented in Figure C.7 in Appendix C.

Stage-Discharge Function

The procedures and guidelines presented in the SCS Technical Release 39 (TR-39) were used to compute the emergency spillway stage-discharge relationship at the downstream end of the Spook Hill FRS. A combined stage-discharge relationship was developed for the emergency and principal spillways. The principal spillway relationship is based on the SCS as-builts.

A comparison between the SCS as-built emergency spillway rating curve and the rating curve developed by DMJM+HARRIS is presented in the white paper in Appendix D and Figure C.8. As shown in Figure C.8, both of these curves present similar stage-discharge characteristics.

## 4.9 Signal Butte Inflow Hydrograph

The Signal Butte Floodway inflow hydrograph was developed to define the inflow design flood for the Spook Hill FRS. The inflow hydrograph is required to model

the contribution of the upper segments of the Buckhorn Mesa watershed, in terms of the peak discharge and volume, into the Spook Hill FRS. The details of this analysis are presented in a white paper in Appendix D.

The resulting peak inflow for the full and one-half PMF was 2,872 cfs at the inlet to the Spook Hill FRS. The average flow volumes (6-hr storm) at the inlet of the Spook Hill FRS are 1,034 ac-ft and 752 ac-ft for the full and one-half PMF events, respectively.

## 4.10 Local Storm vs. General Storm PMF

The general and local storm PMF's were generated using the guidelines described in Section 4. The impact of the local and general storm on representative urban and rural subbasins is summarized in Table 20.

As illustrated below, the local PMF results in higher peak flow and volume estimates than the general PMF. The difference is mainly due to the size of the contributing watershed. In general, the local storm results in higher peak flows than the general storm for watersheds smaller than 40-50 square miles.

**Table 20 - Comparison of General and Local Storms**

| Subbasin No. | Peak Discharge (cfs) | | Peak Volume (ac-ft) | |
|---|---|---|---|---|
| | General | Local | General | Local |
| B1 | 3,254 | 11,044 | 1,889 | 2,051 |
| C1 | 2,055 | 10,683 | 1,200 | 1,297 |

## 4.11 Results

The existing condition hydrologic models along the Spook Hill FRS was developed using the parameters and procedures described in this section. These models are recommended to be the basis of future hydrologic and hydraulic analyses for the design of the Red Mountain Freeway. The results of the hydrologic analyses for the full PMF and one-half PMF conditions are summarized in Table 21 on the following page. The HEC-1 input and output files for the design peak discharges presented in Table 21 are provided in Appendix E.

**Table 21 - Design Peak Discharges**

| Subbasin No. | Peak Discharge (cfs) | |
|---|---|---|
| | PMF | ½ PMF |
| A1 | 3,197 | 1,598 |
| B1 | 11,044 | 5,522 |
| B2 | 2,907 | 1,454 |
| C1 | 10,683 | 5,341 |
| D1 | 4,833 | 2,417 |

The PMF hydrology is based on the Probable Maximum Precipitation. The PMP was estimated for both a general and local storm using procedures in HMR 49. The local storm was selected as the most critical for existing conditions. The procedures and guidelines presented in the FCDMC Hydrology Manual were used to develop the rainfall loss parameters and rainfall-excess to runoff transformation functions.

The hydrologic characteristics of the Spook Hill FRS including the peak inflow, outflow, maximum runoff volume and water-surface elevation are summarized and compared with previous studies in the following section of this report. The peak inflow for the full PMF and one-half PMF are 28,208 cfs and 15,540 cfs, respectively. These inflow hydrographs result in maximum storage volumes of 3,139 acre-feet and 2,081 acre-feet and provide an estimated residual freeboard of 2.5 feet and 5.5 feet for the full PMF and one-half PMF, respectively.

# 5.0 SUMMARY

The peak flow estimates for existing conditions are lower than the peak flow estimates developed for the original SCS design. This difference is mainly due to the methods used to compute time of concentration ($T_c$). As summarized in Section 2, an empirical method was used by SCS to define the time of concentration. The methodology developed in this report is based on the procedures defined in Section 4. The residual freeboard documented in previous reports and the results of the current study are summarized below in Table 22.

**Table 22 - Hydrologic Summary**

| Hydrologic Variable | Unit | Recommended | | Inspection Report | | SCS Design |
|---|---|---|---|---|---|---|
| | | PMF | 1/2 PMF | PMF | 1/2 PMF | Freeboard Hydrograph |
| Storm Duration | Hours | 6 | 6 | 6 | 6 | 6 |
| Storm Precipitation | Inches | 12.8 | - | 12.8 | - | 13.0 |
| Peak Hour | Inches | 9.4 | - | 9.5 | - | - |
| Peak Inflow | cfs | 28,208 | 15,540 | 55,767 | 27,883 | 47,315 |
| Peak Outflow | cfs | 14,478 | 5,920 | 27,681 | 10,367 | 21,286 |
| Storage Volume | Ac-ft | 3,139 | 2,081 | 6,405 | | 5,994 |
| Maximum W.S. Elevation[1] | Feet | 1,588.5 | 1,585.5 | 1,593.08 | 1,589.25 | 1,589.38 |
| Top of Dam Elevation[1] | Feet | 1,591.0 | 1,591.0 | 1,591.0 | 1,591.0 | 1,591.0 |
| Residual Freeboard | Feet | 2.5 | 5.5 | -0.22 | 3.61 | 1.62 |

[1] Elevations are based on NGVD 29 datum.

The hydrologic variables and water-surface elevations presented in Table 22 are based on hydrologic routing and will be refined with the hydraulic analysis and presented in Technical Report No. 2.

# REFERENCES

Arizona Department of Transportation, "Highway Drainage Design Manual, Hydrology," March 1993.

Arizona Department of Transportation (Environmental Planning Section), Federal Highway Administration, and U.S. Army Corps of Engineers, "Red Mountain Freeway (Loop 202) State Route 87 to US Route 60, Final Environmental Impact Statement/ Section 4(F) Evaluation," June 1999.

Arizona Department of Transportation, Surface Water Management Division, "Rules and Regulations Pertaining to Dam Safety Procedures," June 2000.

Daniel, Mann, Johnson, & Mendenhall, "Red Mountain Freeway (202L), Power Road to University Drive, Spook Hill Floodwater Retarding Structure, Technical Report No. 1 (Draft), Existing Condition Hydrology," prepared for the Arizona Department of Transportation, January 2001.

Ertec Western, Inc., "Phase I Inspection Report for Spook Hill Retarding Dam, I.D. No. AZ00175," August 1981.

Flood Control District of Maricopa County, "Drainage Design Manual for Maricopa County, Arizona, Volume I, Hydrology," 1995.

Flood Control District of Maricopa County, "Drainage Design Management System, User's Manual," 2001.

Kimley-Horn & Associates, Inc., "Structures Assessment Program – Phase I, Individual Structures Assessment Report, Spook Hill FRS, Signal Butte FRS, Apache Junction FRS," prepared for the Flood Control District of Maricopa County, April 2001.

Papadakis, C. N., and Kazan, M. N., "Time of Concentration in Small, Rural Watersheds," Proceedings of the Engineering Hydrology Symposium, ASCE, Virginia, 1987.

Soil Conservation Service, "National Engineering Handbook, Section 4, Hydrology," August 1972.

Soil Conservation Service, "Hydrology-Buckhorn Mesa Watershed-Spook Hill Reservoir," (Evaluation of Preliminary Design Report), May 1975.

Soil Conservation Service, "Buckhorn-Mesa WPP, AZ, Spook Hill FRS, Final Design," December 1976.

Soil Conservation Service, "Simplified Dam-Breach Routing Procedure, Technical Release No. 66 (TR-66)," 1990.

Soil Conservation Service, "TR-20 Computer Program for Project Formulation Hydrology," February 1992.

U.S. Army Corps of Engineers, "EM1110-2-1411," 1952.

U.S. Army Corps of Engineers, "Hydrometeorological Report No. 49," September 1977.

U.S. Army Corps of Engineers, "HEC-1 Flood Hydrograph Package User's Manual," Hydrologic Engineering Center, 1990.

U.S. Army Corps of Engineers, HEC-1 Computer Program, Version 4.1, 1998.

U.S. Army Corps of Engineers, HEC-1 Dam Safety Computer Program, 1980.

Wood, M. K., and W. H. Blackburn, "An Evaluation of the Hydrologic Soil Groups as Used in the SCS Runoff Method on Rangelands," Water Resources Bulletin, Vol. 20, pp. 379-389, 1984.

Wood, Patel & Associates, Inc., "Spook Hill Area Drainage Master Plan Update," (ongoing).

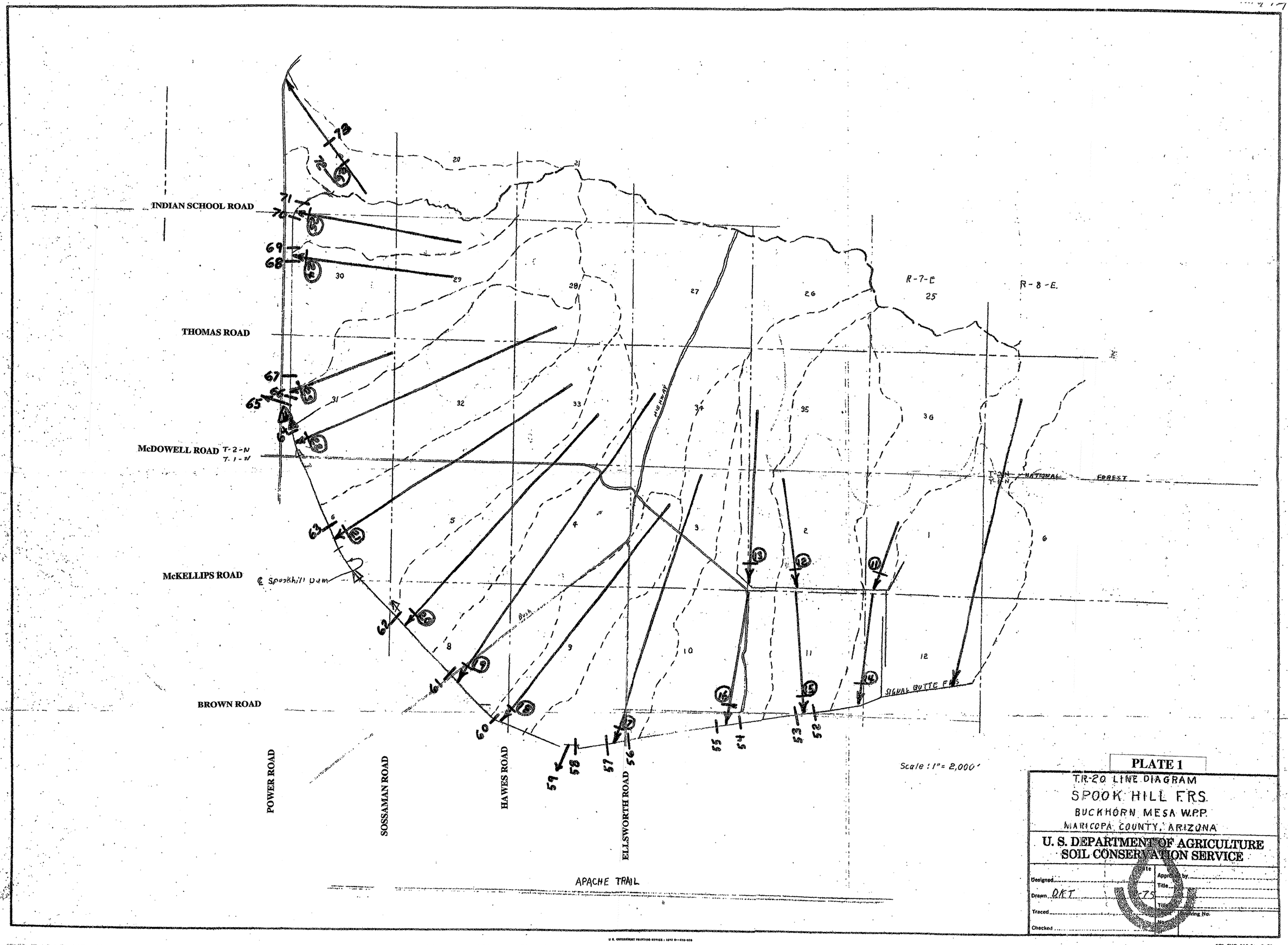



PLATE 1

T.R-20 LINE DIAGRAM
SPOOK HILL F.R.S.
BUCKHORN MESA W.P.P.
MARICOPA COUNTY, ARIZONA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed
Drawn DKT
Traced
Checked
Date
Approved by
Title
Title
Drawing No.

SCS-ENG-313 Rev. 8-72

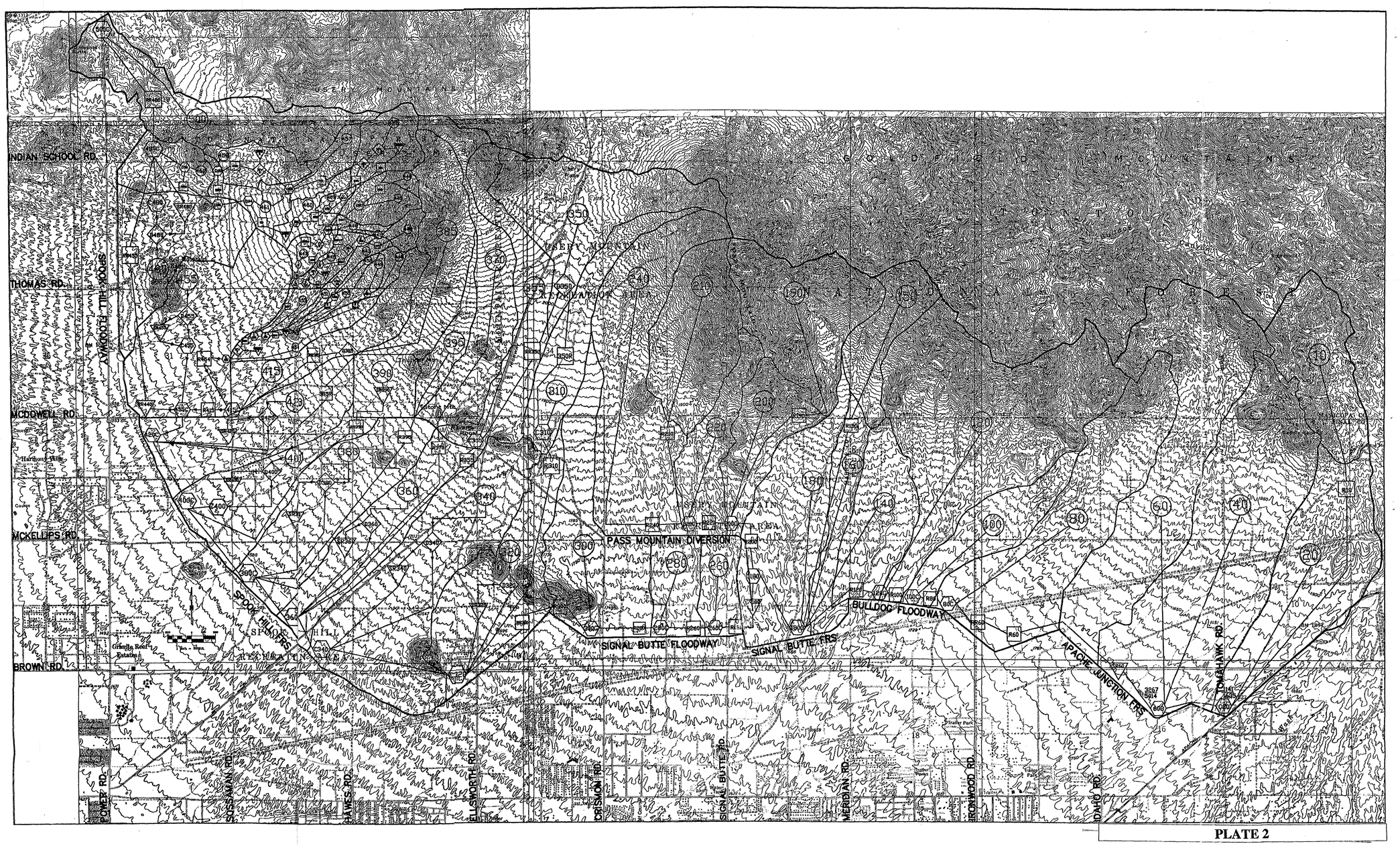

INDIAN SCHOOL RD
THOMAS RD
MCDOWELL RD
MCKELLIPS RD
BROWN RD
POWER RD
SPOOK HILL FWY
SPOOK HILL FRS
SIGNAL BUTTE FLOODWAY
SIGNAL BUTTE FRS
PASS MOUNTAIN DIVERSION
BULLDOG FLOODWAY
APACHE JUNCTION FRS
TOMAHAWK RD
SIGGMAN RD
HAWES RD
ELLSWORTH RD
CRISSON RD
SIGNAL BUTTE RD
MERIDIAN RD
IRONWOOD RD
IDAHO RD
Granite Reef Estates
Trailer Park

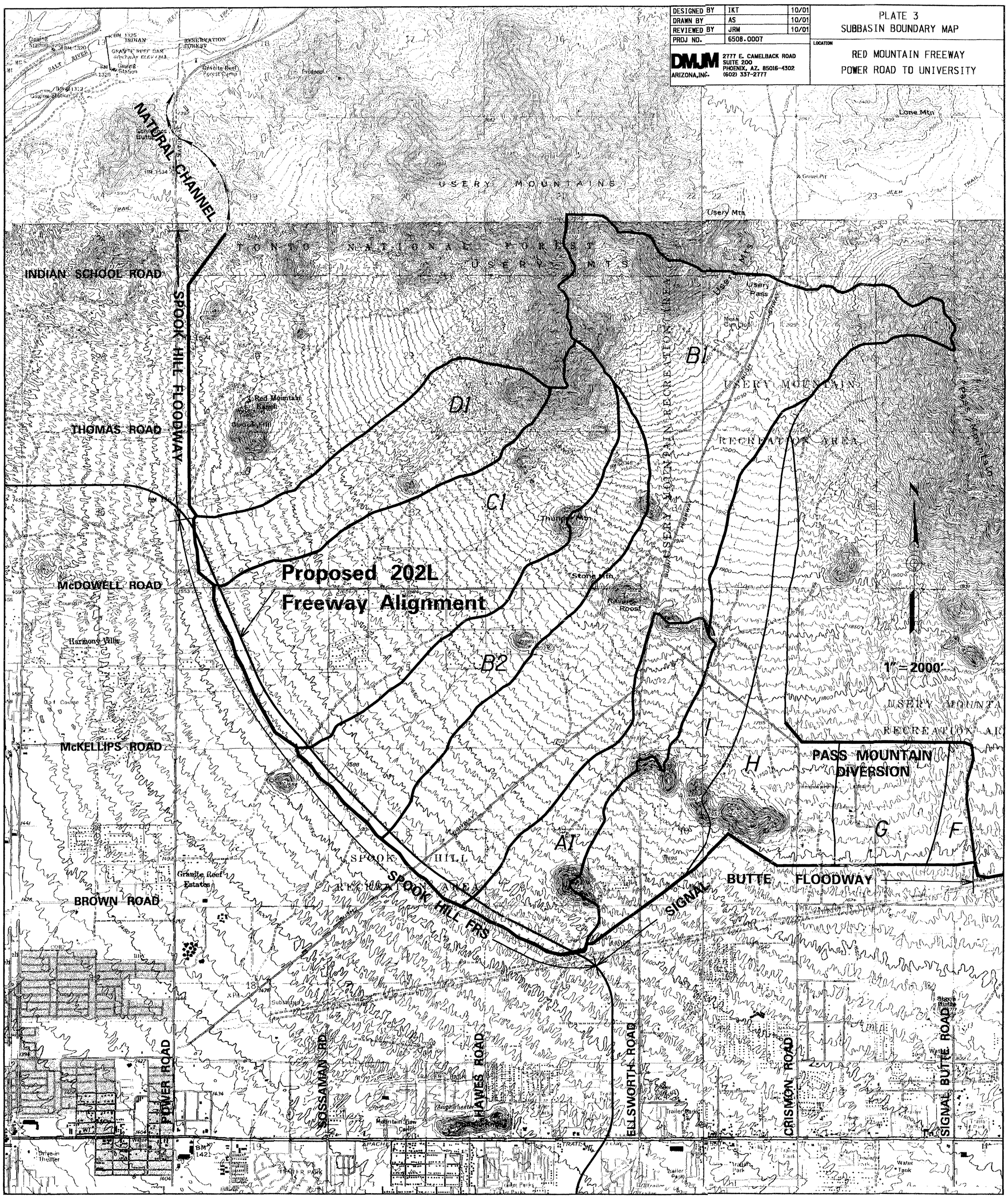
PLATE 2

| | | |
|---|---|---|
| DESIGNED BY | IKT | 10/01 |
| DRAWN BY | AS | 10/01 |
| REVIEWED BY | JRM | 10/01 |
| PROJ NO. | 6508.0007 | |

DMJM ARIZONA, INC.
2777 E. CAMELBACK ROAD
SUITE 200
PHOENIX, AZ. 85016-4302
(602) 337-2777

PLATE 3
SUBBASIN BOUNDARY MAP

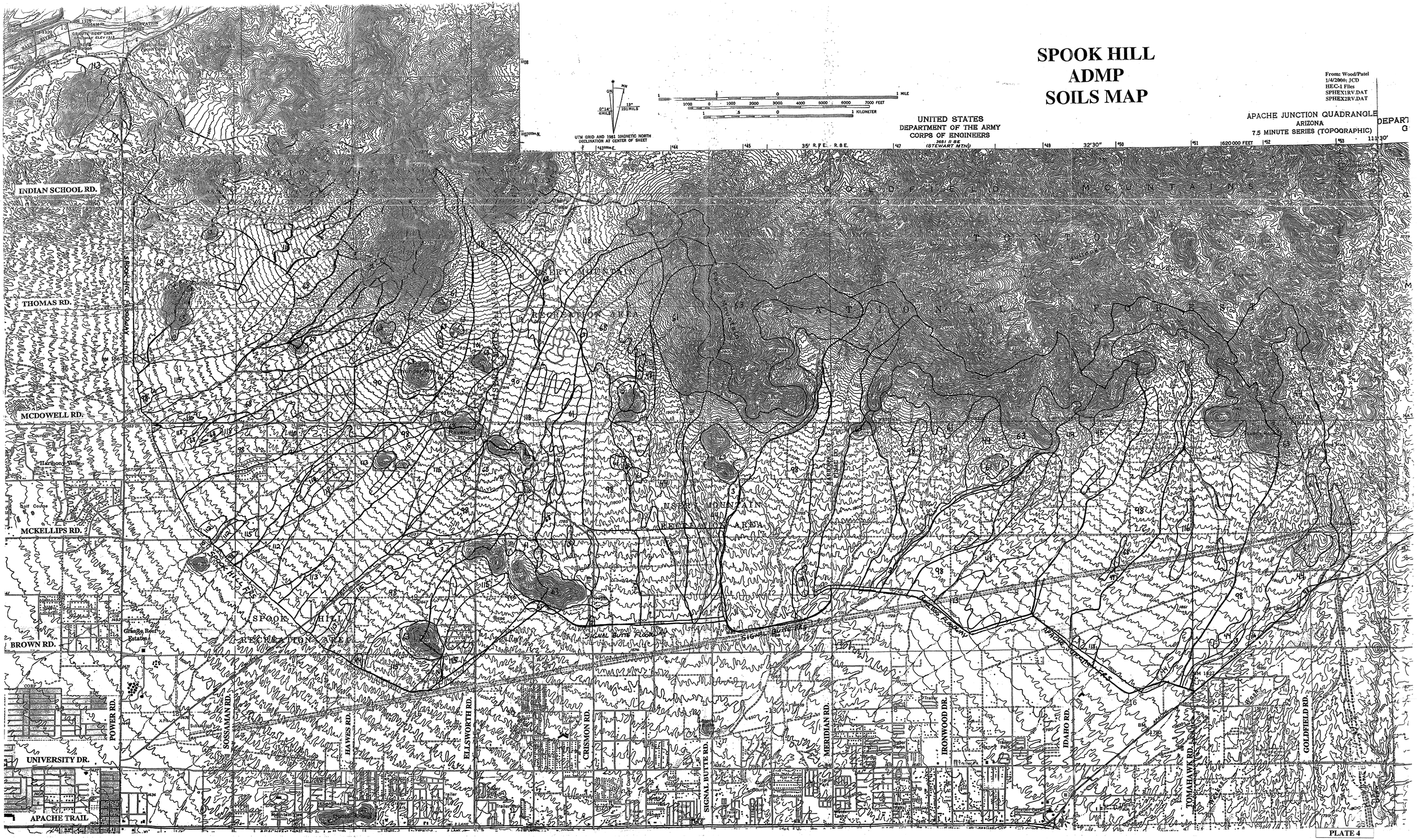
LOCATION
RED MOUNTAIN FREEWAY
POWER ROAD TO UNIVERSITY

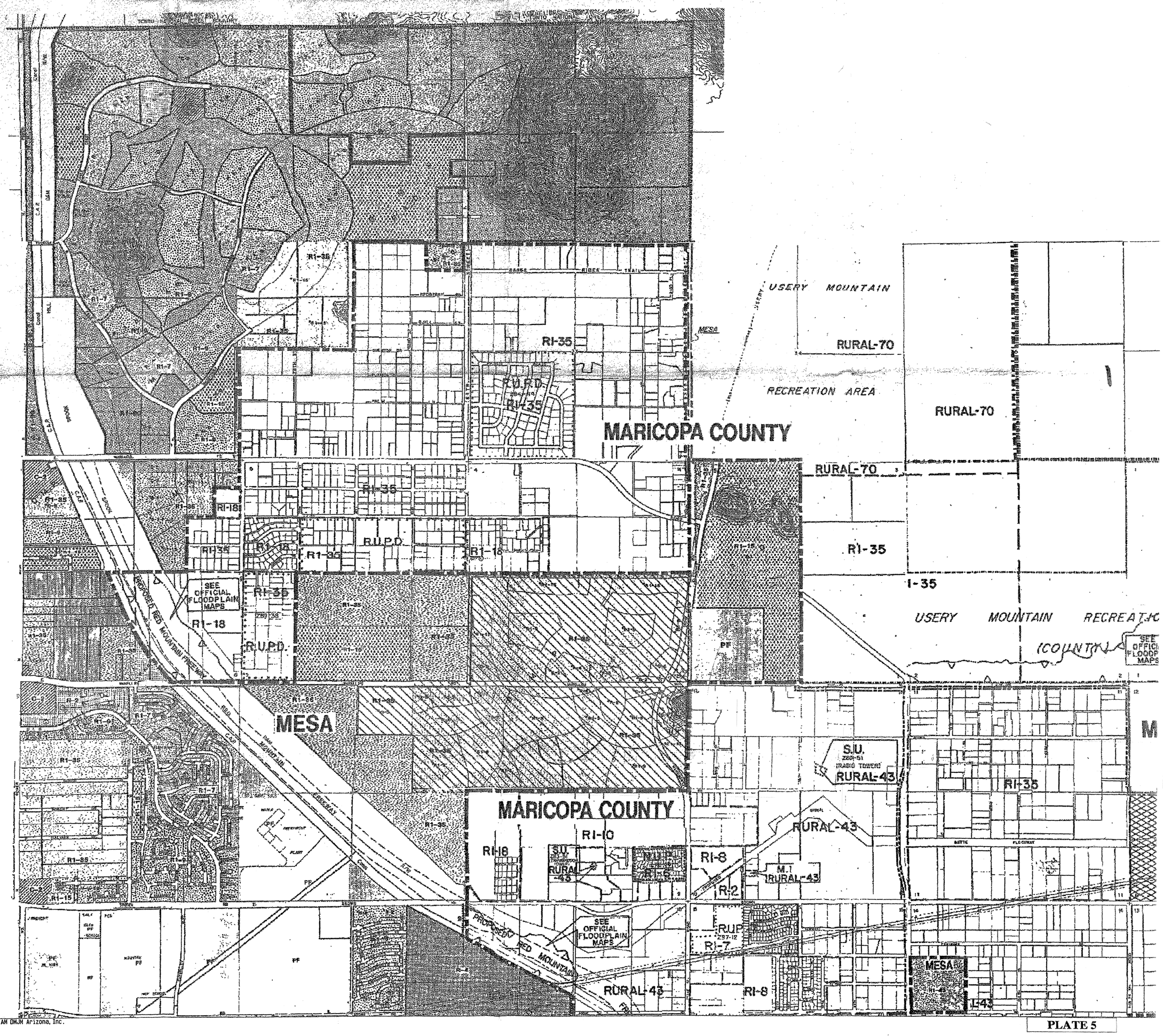



J:\rm06\design\drn\hydrology\report\final report\plate 3.dgn

# SPOOK HILL ADMP SOILS MAP

From: Wood/Patel
1/4/2000: JCD
HEC-1 Files
SPHEX1RV.DAT
SPHEX2RV.DAT






..\Design\drn\WPA\landuse.dgn 11/07/00 10:43:57 AM DMJM Arizona, Inc.

PLATE 5

CITY OF MESA

*Great People, Quality Service!*

# Zoning Map

**Revised: July 2000**

**Notes:**

**Town Center Zoning Map and Legend on separate handout.**


**Planning Division**
**55 N. Center St. P.O. Box 1466**
**Mesa, Arizona 85211-1466**
**Phone: (480) 644-2385 Fax: (480) 644-2757**

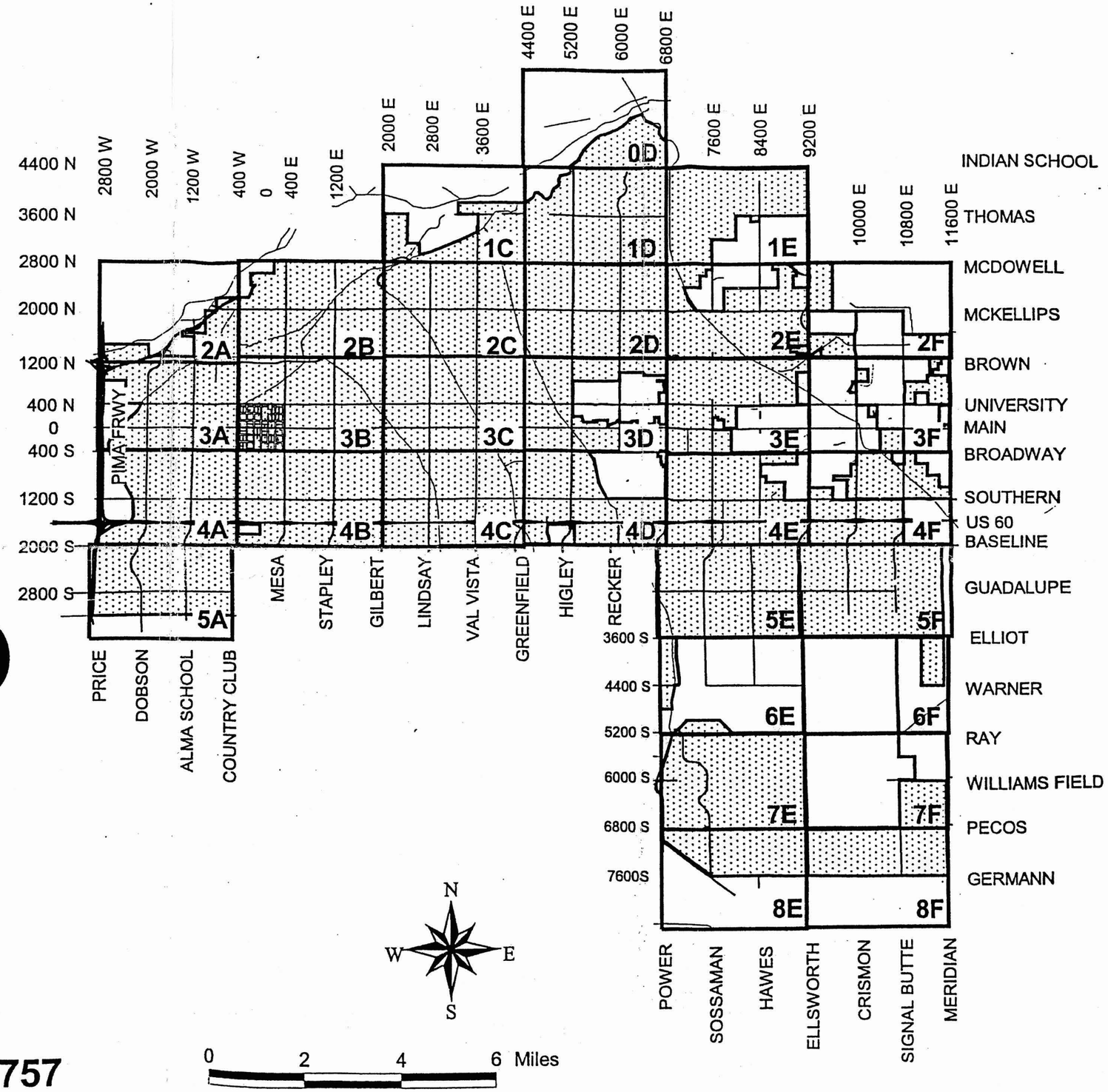
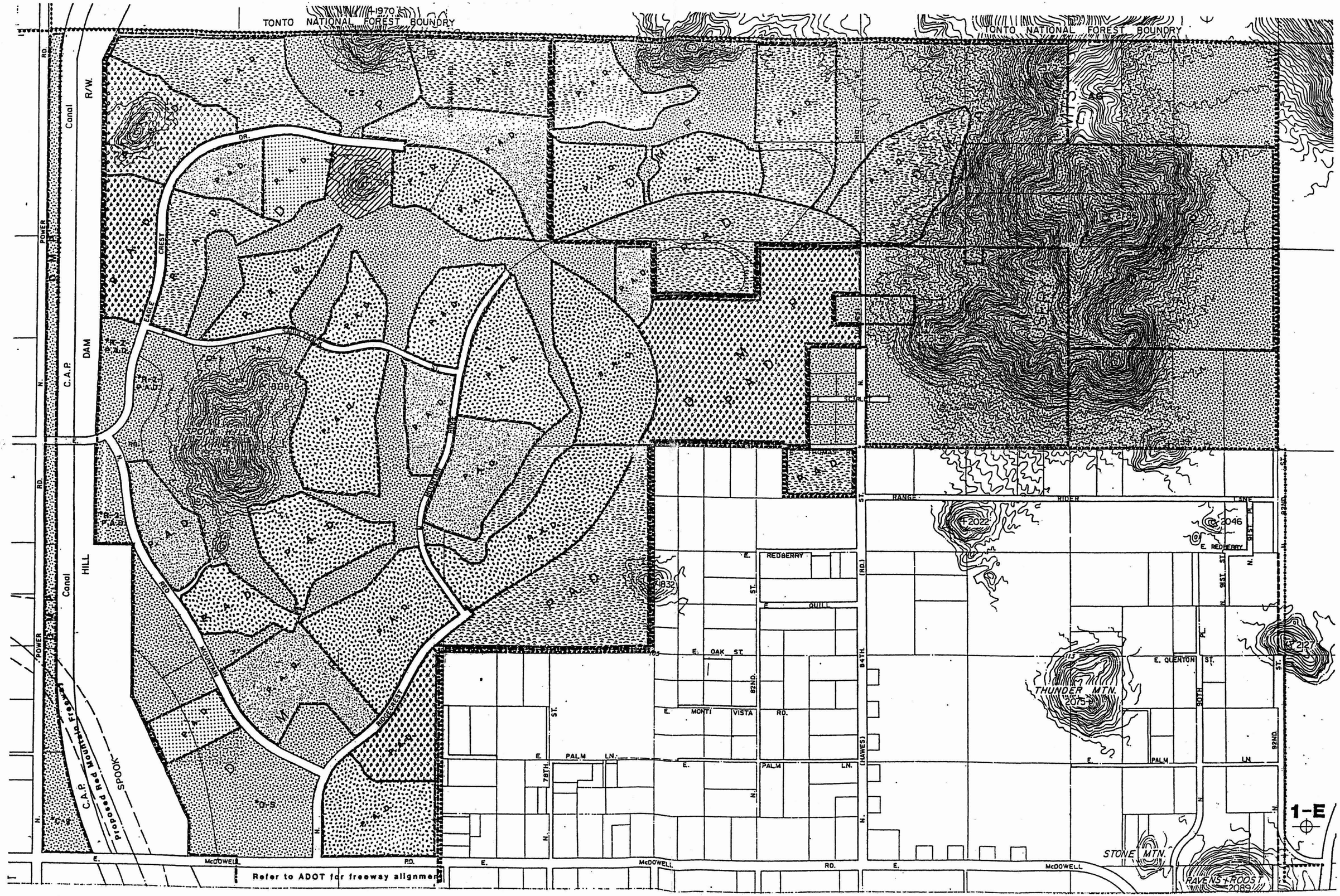
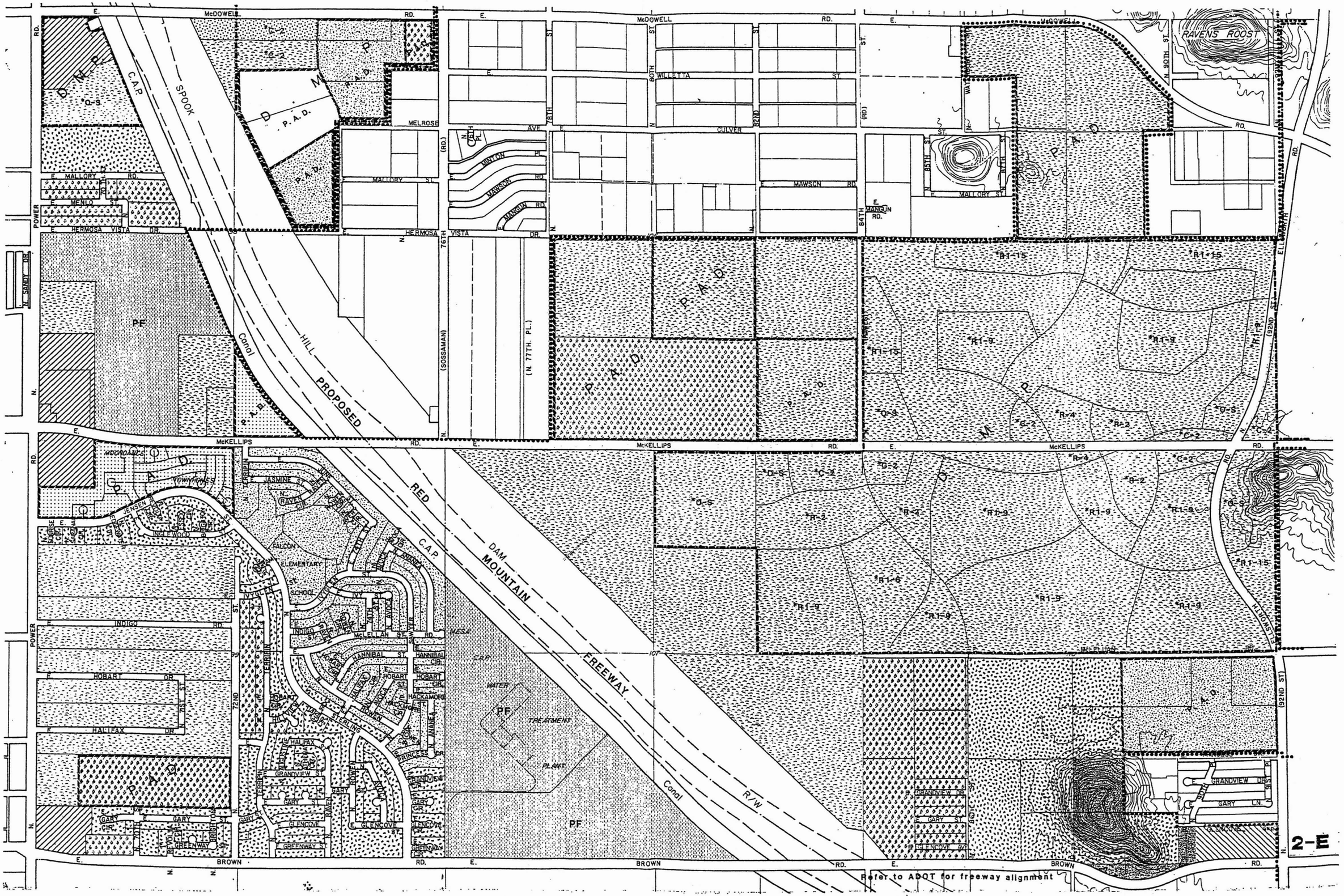
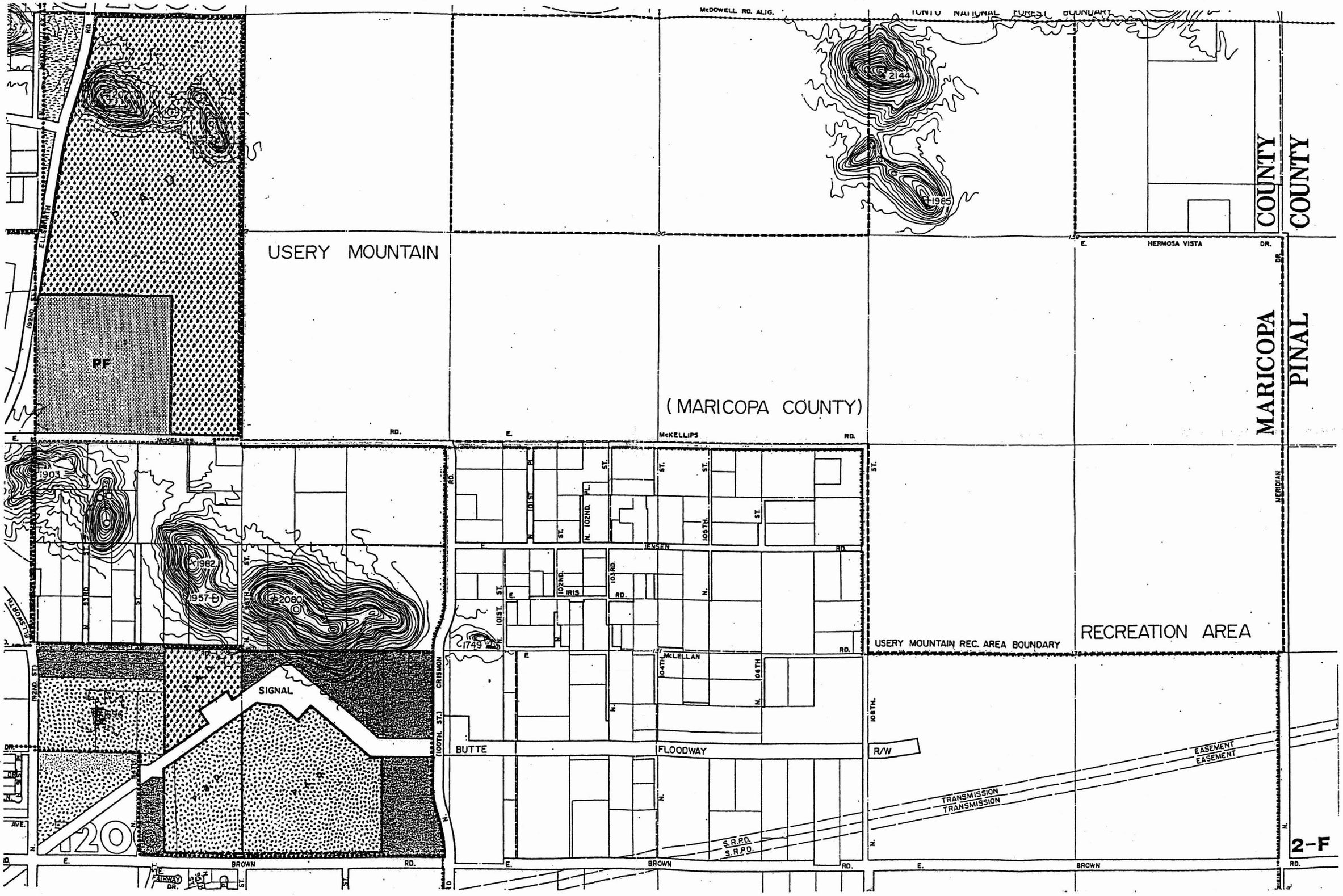




PLATE 6


TONTO NATIONAL FOREST BOUNDRY
TONTO NATIONAL FOREST BOUNDRY
C.A.P. Canal
R/W.
POWER
DAM
HILL
SPOOK
C.A.P.
Proposed Red Mountain Freeway
Refer to ADOT for freeway alignment
McDOWELL RD.
E. McDOWELL RD.
E. McDOWELL
EAGLE CREST DR.
RIDGE CREST
MOUNTAIN
SADDLE
SPOOK HILL
SCENIC DR.
RIDGE
RANGE RIDER LANE
E. REDBERRY
E. QUILL
E. OAK ST.
E. MONTI VISTA RD.
E. PALM LN.
E. QUENTON ST.
N. 84TH ST. (HAWES)
N. 78TH ST.
N. 82ND ST.
N. 90TH ST.
N. 91ST ST.
N. 91ST PL.
N. 92ND ST.
THUNDER MTN.
STONE MTN.
RAVENS ROOST
1832
2022
2046
2075
2089
2127
1-E


McDOWELL RD.
McKELLIPS RD.
BROWN RD.
POWER RD.
N. SANDY DR.
ELLSWORTH RD.
N. 90TH ST.
RAVENS ROOST
WILLETTA ST.
CULVER ST.
MAWSON RD.
MALLORY ST.
MELROSE AVE.
HERMOSA VISTA DR.
SPOOK HILL
PROPOSED
RED MOUNTAIN FREEWAY
C.A.P.
Canal
R/W
DAM
MESA
WATER TREATMENT PLANT
PF
P.A.D.
R1-15
R1-9
R-4
R-2
C-2
O-S
C-X
R1-6
JASMINE ST.
RAVEN CIR.
FALCON ELEMENTARY SCHOOL
INDIGO RD.
HOBART DR.
HALIFAX DR.
GARY ST.
GLENCOVE ST.
GREENWAY ST.
GRANDVIEW DR.
GARY LN.
Refer to ADOT for freeway alignment
2-E


McDOWELL RD. ALIG.
TONTO NATIONAL FOREST BOUNDARY
2144
1985
COUNTY
COUNTY
USERY MOUNTAIN
E. HERMOSA VISTA DR.
MARICOPA
PINAL
PF
(MARICOPA COUNTY)
E. McKELLIPS RD.
1903
1982
1957
2080
1749
1696
SIGNAL
120
101ST. ST.
102ND. PL.
103RD. ST.
105TH. ST.
JENSEN RD.
IRIS RD.
McLELLAN RD.
104TH. ST.
106TH. ST.
CRISMON (100TH. ST.)
192ND. ST.
ELLSWORTH RD.
MERIDIAN
USERY MOUNTAIN REC. AREA BOUNDARY
RECREATION AREA
BUTTE FLOODWAY R/W
EASEMENT
EASEMENT
TRANSMISSION
TRANSMISSION
S.R.P.D.
S.R.P.D.
E. BROWN RD.
FAIRWAY DR.
2-F

# APPENDIX A

## Definitions

# DEFINITIONS

**Attenuation-Kinematic Method:** A channel routing process based on the procedures described in TR-66 (1981).

**Classification of Dams:** The placement of dams into categories based upon an evaluation of the size and hazard potential, regardless of the condition of the dam.

**Embankment Dam:** A dam that is constructed of earth or rock material.

**Emergency Spillway:** A spillway designed to safely pass the inflow design flood routed through the reservoir. If gates control the flow, it is a controlled spillway. If gates do not control flow, it is an uncontrolled spillway.

**Emergency Spillway Hydrograph (ESH):** The hydrograph used in the design of the emergency spillway. Procedures and guidelines presented in NEH 4 (Chapter 21) can be used to construct the ESH. The method requires the use of dimensionless hydrographs.

**Flood Control Dam:** A dam that uses all of its reservoir storage capacity for temporary impoundment of floodwaters and collection of sediment and debris.

**Freeboard Hydrograph (FH):** The hydrograph used to define the minimum freeboard of the emergency spillway and top of dam. Procedures and guidelines presented in NEH 4 (Chapter 21) can be used to construct the FH.

**Hazard Potential:** A system that categorizes dams according to the degree of possible incremental adverse consequences of failure or improper operation of a dam or appurtenances. The hazard potential classification does not reflect the current condition of the dam with regard to safety, structural integrity, or flood routing capacity.

**Height:** The vertical distance from the lowest elevation of the outside limit of the barrier at its intersection with the natural ground surface to the spillway crest elevation. For the purpose of determining jurisdictional status, the lowest elevation of the outside limit of the barrier may be the outlet pipe invert elevation if the outlet is constructed below natural ground.

**Inflow Design Flood:** The reservoir inflow magnitude selected on the basis of size and hazard potential classification for emergency spillway design requirements of a dam.

**Jurisdictional Dam:** A barrier that meets the definition of a dam prescribed in A.R.S. 45-1201 that is not exempted by R12-15-1203 over which the Arizona Department of Water Resources (ADWR) exercises jurisdiction.

**License:** A license of final approval issued by the Director of ADWR upon completion or enlargement of a dam under A.R.S. 45-1209.

**Maximum Water Surface:** The maximum elevation of the reservoir water level attained during routing of the inflow design flood.

**Principal Spillway:** A concrete or metal pipe or conduit used with a drop inlet dam or floodwater retarding structure. It conveys, in a safe and non-erosive manner, all ordinary discharges coming into a reservoir and all of an extreme amount that does not pass through the emergency spillway.

**Principal Spillway Hydrograph:** The Soil Conservation Service (SCS) criteria require principal spillway capacity and the associated floodwater retarding storage to be such that project objectives are met and the frequency of the emergency spillway operation is within specified limits. The criteria are met by use of a Principal Spillway Hydrograph (PSH) or its mass curve, which are developed from tabulations given NEH 4 (Chapter 21).

**Probable Maximum Flood (PMF):** The flood runoff expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region, including rain and snow where applicable. One-half PMF is that flood represented by the flood hydrograph with ordinates equal to one-half the corresponding ordinates of the PMF hydrograph.

**Probable Maximum Precipitation (PMP):** The greatest depth of precipitation for a given duration that is theoretically physically possible over a particular size storm area at a particular geographical location at a particular time of year.

**Reservoir:** Any basin that contains or is capable of containing water impounded by a dam.

**Residual Freeboard:** The vertical distance between the highest water surface elevation during the inflow design flood and the lowest point at the top of the dam.

**Spillway Crest:** The highest elevation of the floor of the spillway along a centerline profile through the spillway.

**Storage Capacity:** The maximum volume of water, sediment or debris that can be impounded in the reservoir with no discharge of water, including the situation where an uncontrolled outlet becomes plugged. The storage capacity is reached when the water level is at the crest of the emergency spillway, or at the top of permanently mounted emergency spillway gates in the closed position. Storage capacity excludes dead storage below the natural ground surface.

**Storage-Indication Method:** A reservoir-routing method based on the principles of level pool reservoir routing.

**Total Freeboard:** The vertical distance between the emergency spillway crest and the top of the dam.

**Unit Hydrograph:** The direct runoff hydrograph resulting from unit depth of excess rainfall produced by a storm of uniform intensity and specified duration.

# APPENDIX B

## SCS Design

# Appendix B1

# Evaluation of Preliminary Design Report

United States Department of Agriculture

Soil Conservation Service

West National Technical Center
511 NW Broadway, Room 248
Portland, Oregon 97209-3489

Subject: PDM - Spookhills Reservoir Hydrology, Buckhorn Mesa Watershed, Arizona

Date: January 7, 1988

To: Robin McArthur, Hydraulic Engineer, SCS, Phoenix, Arizona

File code:

Enclosed is our review copy of the hydrology studies for the Spookhills Flood Water Retarding Structure (FRS) in the Buckhorn Mesa Watershed. The file contains some of the data that will be necessary if you reevaluate the hydrology in conjunction with the Arizona Department of Transportations request to locate an expressway in the FRS.

You may keep the file.

Larry J Babich

LARRY BABICH
Planning Engineer

Enclosure

cc: (w/o encl.)
Clarence M. Maesner, Head, ESP, WNTC
Wendell Styner, Hydraulic Engineer, Engineering Staff, WNTC

West Technical Service Center, Portland, Oregon 97209

ENG - Hydrology-Buckhorn Mesa Watershed-
Spookhills Reservoir

May 8, 1975

Paul Monville, Civil Engineer
Design Unit, Phoenix, Arizona

We have carefully reviewed the design hydrology for Spookhill Reservoir in the Bukhorn Mesa , as requested during your recent trip to Portland.

The computations for determining the required floodwater regarding capacity, principal spillway size, and the emergency spillway crest are satisfactory. However, 24 hour runoff curve numbers were used to develop the emergency spillway design and free board hydrographs. Six hour runoff curve numbers should have been used.

Arizona can vary runoff curve with duration in the developmentoof the emergency spillway and freeboard hydrograph, according to an April 1, 1975 memorandum from Paul Tilker to George Marks. The runoff curve number in Figure 9.5 and 9.6 in HEH-4 or Figure 10 in the Arizona Hydrology Handbook, should be used with one hour duration storms The runoff curves for a six hour storm should be determind using Figure 4 in the ASAE Paper 73-209, entitled "Runoff Curve Numbers for Semiarid and Arid Range lands.

A revised Hp value was determined using six hour runoff curve numbers and the proposed emergency spillway configuration. The computation indicated the revised top of the dam should be 1589.6 of .3' higher. A copy of the computations are attached for your information.

Wendell Styner
Hydraulic Engineer

Attachment

USDA-SCS:mar

| STATE | | PROJECT | | |
|---|---|---|---|---|
| Arizona | | Buckhorn Mesa - Spook Hill F.R.S. | | |
| BY Burton | DATE 2/28/75 | CHECKED BY | DATE | JOB NO. 2005 |
| SUBJECT P.M.P. for Design - Spook Hill F.R.S. | | | | SHEET ___ OF ___ |

Use report: "Probable Maximum Thunderstorm Precipitation Estimates Southwest States"

Spook Hill F.R.S. Drainage Area = 13.57 Sq. Miles

From figure # 23:

1hr - 1sq. mi PMP = 11.5 inches

Elevation is < 5000 M.S.L.
∴ No adjustment needed.

From figure # 24:
6 hr/1 hr (100) = 130

| 6 hr/1 hr ratio | | 1/4 | 1/2 | 1.0 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|
| 1.3 | % 1hr. | 74 | 89 | 100 | 114 | 121 | 125 | 128 | 130 |
| | inches | 8.5 | 10.2 | 11.5 | 13.1 | 13.9 | 14.4 | 14.7 | 14.95 |
| Reduction Factor | | .69 | .73 | .78 | .82 | .83 | .85 | .86 | .87 |
| Rainfall | | 5.9 | 7.5 | 9.0 | 10.7 | 11.5 | 12.2 | 12.6 | 13.0 |

Determine Design Precipitation:

Design Hydrograph:

$$P = P_{100} + 0.26(PMP - P_{100})$$

$$= 100\ Yr - 6hr\ Prec = (3.2)(0.97) = 3.1$$

$$P = 3.10 + 0.26(13.0 - 3.10)$$
$$= 5.67 \text{ inches}$$

Freeboard Hydrograph
P = 13.0 inches ✓ [illegible] 4/75

SPOOK HILL FRS

SCS-271
6-64

CUMULATIVE RAINFALL TABLE, NORMALIZED OR ACTUAL

Watershed BUCKHORN MESA Hydrologist BURTON Date 3/3/75

| DATA CODE | TABLE NAME | TABLE NO. (1-9) | DATA FIELD #1 | DATA FIELD #2 | DATA FIELD #3 | DATA FIELD #4 | DATA FIELD #5 | CARD NO./ IDENTIFICATION |
|---|---|---|---|---|---|---|---|---|
| | | | IMPORTANT: Line out unused cards. Data fields require decimal points. KEYPUNCHER: Left justify data fields. | | | | | |
| | | | TIME INCREMENT, HRS. | | | | | |
| 5 | RAINFL | 2 | | 0.02 | | | | 4 |
| | | | IMPORTANT: For normalized table, must have: (no. of entries) • (time increment) ≧ 1. | | | | | |
| | | | Enter successive entries left to right with initial entry for time = 0. Fill last row of data with last entry of table. | | | | | |
| 8 | | | 0.0 | 0.002 | 0.005 | 0.008 | 0.0110 | 4 |
| 8 | | | 0.0150 | 0.019 | 0.024 | 0.030 | 0.036 | 4 |
| 8 | | | 0.0420 | 0.050 | 0.058 | 0.068 | 0.076 | 4 |
| 8 | | | 0.0880 | 0.100 | 0.125 | 0.175 | 0.235 | 4 |
| 8 | | | 0.3000 | 0.380 | 0.470 | 0.575 | 0.695 | 4 |
| 8 | | | 0.8150 | 0.837 | 0.853 | 0.867 | 0.880 | 5 |
| 8 | | | 0.8920 | 0.903 | 0.913 | 0.922 | 0.930 | 5 |
| 8 | | | 0.9380 | 0.945 | 0.951 | 0.957 | 0.962 | 5 |
| 8 | | | 0.9670 | 0.972 | 0.975 | 0.978 | 0.982 | 5 |
| 8 | | | 0.9850 | 0.987 | 0.991 | 0.994 | 0.997 | 5 |
| 8 | | | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 5 |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | ENDTBL | | | | | | | 5 |

* GPO: 1972 —440-109

STATE Arizona | PROJECT Buckhorn Mesa WPF - Smoky Hill FPS

BY Burton | DATE 3/19/72 | CHECKED BY | DATE | JOB NO. 2005

SUBJECT Hydrology - Drainage Areas | SHEET ____ OF ____

| Drainage Area No. | Drainage Area B Soils ($Mi^2$) | Drainage Area D Soils ($Mi^2$) | Total Drainage Area ($Mi^2$) | |
|---|---|---|---|---|
| 11 | 0.37 | 1.19 | 1.56 | |
| 12 | 0.80 | 0.74 | 1.54 | |
| 13 | 0.65 | 0.36 | 1.01 | |
| 14 | 0.25 | — | 0.25 | |
| 15 | 0.68 | — | 0.68 | |
| 16 B | 1.22 | — | 1.22 | Floodway |
| 17 | 1.44 | — | 1.44 | |
| 18 | 0.92 | — | 0.92 | |
| 19 | 3.75 | 0.33 | 4.08 | |
| 20 | 1.28 | — | 1.28 | FWS |
| 21 | 1.75 | 0.16 | 1.91 | |
| 22 | 1.08 | 0.71 | 1.79 | |
| 23 | 0.53 | 0.39 | 0.92 | |
| 24 | 0.35 | 0.91 | 1.26 | |
| 25 | — | 0.75 | 0.75 | |
| 26 | — | 0.42 | 0.42 | |

1.2

| STATE Arizona | PROJECT Buckhorn Mesa W.P.P. - [illegible] | | | |
|---|---|---|---|---|
| BY Burton | DATE 2/18/75 | CHECKED BY [illegible] | DATE 4/75 | JOB NO. 2005 |
| SUBJECT Hydrology - Runoff Curve Numbers | | | | SHEET ___ OF ___ |

Use RCN's as assumed in 1974 TR-20 analysis of RWCD Floodway by B. Bartels

In the 1974 analysis all land above the Buckhorn Mesa Structures was found to be (a) 100-299 homes/Sq. Mi ; or (b) Range land (Desert Condition).

The following 24 Hr. RCN's were assumed :

(a) Desert Rangeland (B-Soil) - 75

(b) Desert Rangeland (D-Soil) - 86

(c) 100-299 Homes/Sq. Mile - 75

Curve Numbers appear to be the same as for previous designs.

SCS-ENG-523 Rev. 8-69

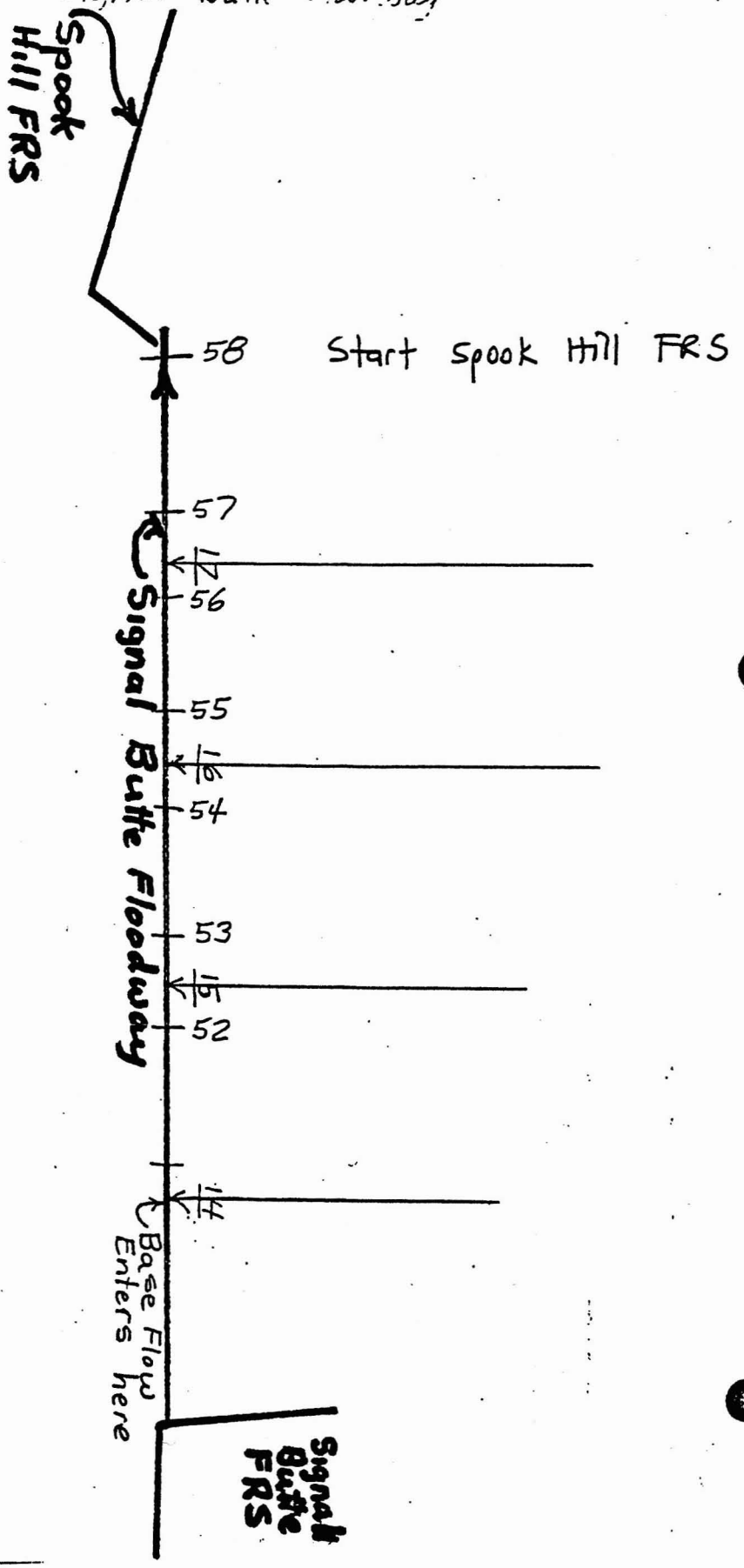
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

* GPO: 1972—460-109

| STATE | PROJECT | | |
|---|---|---|---|
| Arizona | Buckhorn Mesa Wat. - Front Hill Dam | | |
| BY: Furter | DATE: 2/10/75 | CHECKED BY | DATE | JOB NO. 2005 |
| SUBJECT: Hydrology - Runoff Curve Numbers | | | SHEET ___ OF ___ |

| Drainage Area No. | Desert Rangeland B Soil (%) RCN = 75 | Desert Rangeland D Soil (%) RCN = 86 | Weighted RCN (24 Hr) | | |
|---|---|---|---|---|---|
| 11 | 24 | 76 | 83 | | |
| 12 | 52 | 48 | 80 | | |
| 13 | 64 | 36 | 79 | | |
| 14 | 100 | 0 | 75 | .25 | |
| 15 | 100 | 0 | 75 | .62 | |
| 16 | 100 | 0 | 75 | 1.2[illegible] | |
| 17 | 100 | 0 | 75 | 1.[illegible] | |
| 18 | 100 | 0 | 75 | [illegible] | |
| 19 | 92 | 8 | 76 | 4.9[illegible] | |
| 20 | 100 | 0 | 75 | [illegible] | |
| 21 | 92 | 8 | 76 | 1.91 | |
| 22 | 60 | 40 | 79 | [illegible] | |
| 23 | 58 | 42 | 80 | 15.[illegible] mm² | |
| 24 | 28 | 72 | 83 | | |
| 25 | 0 | 100 | 86 | | |
| 26 | 0 | 100 | 86 | | |

Arizona Buckhorn Mesa - Spook Hill FRS
Burton 2/22/75 2005
Line Diagram - Signal Butte Floodway



| STATE Arizona | | PROJECT Buckhorn Mesa - Spring Hill FRS | | |
|---|---|---|---|---|
| BY Furton | DATE 2/13/78 | CHECKED BY | DATE | JOB NO. 1005 |
| SUBJECT Signal Butte Floodway - TR-20 Summary | | | | SHEET ___ OF ___ |

| Drainage Area No. | Peak Q cfs |
|---|---|
| 14 | 185 |
| Baseflow Added | (157 cfs) |
| 52 | 331 |
| 15 | 505 |
| 53 | 825 |
| 54 | 792 |
| 16 | 801 |
| 55 | 1593 |
| 56 | 1493 |
| 17 | 855 |
| 57 | 2347 |
| 58 | 2222 |

1.3 (2222) = 2888 cfs

JOB DUCKHORN MESA

BY BU. N

DATE 3/3/75

WRITTEN AS:

AS.

NOTES TR-20 STANDARD CONTROL

| DATA CODE | SUBROUTINE NAME (1-10) | STATION NO | X-SEC NO | STR NO (20) | HYDROGRAPH IN-PUT | HYDROGRAPH IN-PUT | HYDROGRAPH OUT-PUT | DATA FIELD NO 1 (21-30) | DATA FIELD NO 2 (31-40, 41-50) | DATA FIELD NO 3 (51-60) | OUTPUT OPTIONS PRINT PEAK | HYD | FLOW | VOL | PUNCH | SUM | CAL (IDEN 71-) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | RUNOFF | 1 | 14 | | | | 7 | 0.25 | 75. | 0.38 | | | | | | 1 | 7 |
| 6 | REACH | 3 | 52 | | 7 | | 6 | 2450. | 0.87 | | | | | | | 1 | 7 |
| 6 | RUNOFF | 1 | 15 | | | | 5 | 0.68 | 75. | 0.38 | | | | | | 1 | 7 |
| 6 | ADDHYD | 4 | 53 | | 5 | 6 | 7 | | | | | 1 | | | | 1 | 8 |
| 6 | REACH | 3 | 54 | | 7 | | 6 | 3600. | 0.90 | | | | | | | 1 | 8 |
| 6 | RUNOFF | 1 | 16 | | | | 5 | 1.22 | 75. | 0.56 | | | | | | 1 | 8 |
| 6 | ADDHYD | 4 | 55 | | 5 | 6 | 7 | | | | | 1 | | | | 1 | 8 |
| 6 | REACH | 3 | 56 | | 7 | | 6 | 5200. | 0.95 | | | | | | | 1 | 8 |
| 6 | RUNOFF | 1 | 17 | | | | 5 | 1.44 | 75. | 0.66 | | | | | | 1 | 8 |
| 6 | ADDHYD | 4 | 57 | | 5 | 6 | 7 | | | | | 1 | | | | 1 | 8 |
| 6 | REACH | 3 | 58 | | 7 | | 6 | 2500. | 0.85 | | | | | | | 1 | 8 |
| 6 | DIVERT | 6 | 59 | | 6 | 2 | 1 | 2888. | | | | | | | | 1 | 8 |
| 6 | RUNOFF | 1 | 18 | | | | 7 | 0.92 | 75. | 0.60 | | | | | | 1 | 8 |
| 6 | ADDHYD | 4 | 60 | | 7 | 2 | 6 | | | | | 1 | | | | 1 | 9 |
| 6 | RUNOFF | 1 | 19 | | | | 5 | 4.08 | 76. | 1.19 | | | | | | 1 | 9 |
| 6 | ADDHYD | 4 | 61 | | 5 | 6 | 7 | | | | | 1 | | | | 1 | 9 |
| 6 | RUNOFF | 1 | 20 | | | | 6 | 1.28 | 75. | 0.73 | | | | | | 1 | 9 |
| 6 | ADDHYD | 4 | 62 | | 7 | 6 | 5 | | | | | 1 | | | | 1 | 9 |
| 6 | RUNOFF | 1 | 21 | | | | 6 | 1.91 | 76. | 0.83 | | | | | | 1 | 9 |
| 6 | ADDHYD | 4 | 63 | | 5 | 6 | 7 | | | | | | | | | | 9 |

SITE SPOOK HILL SITE NO. 4 STRUC CLASS C PAGE NO.
BUCKHORN MESA W/S ARIZONA 02-2

BOX CONDUIT DIMENSIONS ARE 9.00 BY 6.00 FEET

| | TIME | INFLOW | AVE IN | OUTFLOW | ELEV. | STORAGE |
|---|---|---|---|---|---|---|
| | 6.00 | 160.87 | 160.85 | 34.40 | 1578.04 | 70.69 |
| | 12.00 | 161.11 | 161.09 | 66.18 | 1578.35 | 124.67 |
| | 18.00 | 161.38 | 161.36 | 95.53 | 1578.58 | 164.07 |
| | 24.00 | 161.68 | 161.65 | 117.37 | 1578.74 | 191.04 |
| | 30.00 | 162.02 | 161.99 | 132.10 | 1578.84 | 209.21 |
| | 36.00 | 162.40 | 162.37 | 142.06 | 1578.91 | 221.51 |
| | 42.00 | 162.84 | 162.80 | 148.87 | 1578.96 | 229.91 |
| | 48.00 | 163.35 | 163.30 | 153.58 | 1578.99 | 235.72 |
| | 54.00 | 163.94 | 163.89 | 157.38 | 1579.02 | 239.71 |
| | 60.00 | 164.65 | 164.58 | 160.00 | 1579.03 | 242.45 |
| | 66.00 | 165.50 | 165.42 | 161.93 | 1579.04 | 244.46 |
| | 72.00 | 166.56 | 166.46 | 163.49 | 1579.05 | 246.09 |
| | 78.00 | 167.89 | 167.77 | 164.91 | 1579.06 | 247.57 |
| | 84.00 | 169.64 | 169.48 | 166.38 | 1579.07 | 249.10 |
| | 90.00 | 172.04 | 171.81 | 168.08 | 1579.08 | 250.87 |
| | 96.00 | 175.54 | 175.19 | 170.25 | 1579.09 | 253.13 |
| | 102.00 | 181.17 | 180.58 | 173.31 | 1579.11 | 256.32 |
| | 108.00 | 191.79 | 190.60 | 178.21 | 1579.14 | 261.42 |
| | 114.00 | 220.29 | 216.43 | 188.09 | 1579.20 | 271.72 |
| | 120.00 | 4798.04 | 2599.58 | 407.45 | 1580.36 | 491.23 |
| PEAK | 122.00 | 852.16 | 1933.12 | 808.63 | 1582.03 | 865.92 |
| | MAXIMUM STORAGE OBTAINED. DRAW-DOWN BEGINS. | | | | | |
| | 1.00 | 156.05 | 156.05 | 238.69 | 1579.51 | 324.21 |
| | 2.00 | 156.05 | 156.05 | 168.32 | 1579.08 | 251.12 |
| | 3.00 | 156.05 | 156.05 | 157.88 | 1579.02 | 240.23 |
| | 4.00 | 156.05 | 156.05 | 156.32 | 1579.01 | 238.61 |
| | 5.00 | 156.05 | 156.05 | 156.09 | 1579.01 | 238.37 |
| | 6.00 | 156.05 | 156.05 | 156.06 | 1579.01 | 238.34 |
| | 7.00 | 156.05 | 156.05 | 156.05 | 1579.01 | 238.33 |
| | 7.62 | 156.05 | 156.05 | 156.05 | 1579.01 | 238.33 |
| | OUTFLOW = INFLOW-ROUTING COMPLETE | | | | | |

US

MAXIMUM STORAGE IS 865.9 ACRE FEET ( 1.196 INCHES) AT ELEV. 1582.03 (CREST, EMER. SPW.).

NET DETENTION STORAGE REQUIRED IS 866.0 ACRE FEET ( 1.196 INCHES).

GROSS STORAGE REMAINING AFTER 10 DAYS IS 238.3 ACRE FEET ( 0.329 INCHES)
AT ELEV. 1579.01 (START EMER. SPW. AND FREEBOARD ROUTINGS).

NET REMAINING STORAGE IS 238.4 ACRE FEET ( 0.329 INCHES).

# Appendix B2

# Final Design Report

BUCKHORN-MESA WPP, AZ

SPOOK HILL F.R.S.

FINAL DESIGN

12-22-76

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ARIZONA STATE OFFICE
PHOENIX, ARIZONA
DECEMBER 22, 1976

# DESIGN REPORT

Job: Spook Hill Floodwater Retarding Structure
Project: Buckhorn-Mesa WPP
Location: Maricopa County, Arizona
Authority: PL 566
Phase: III - Final Design

Summary: The design is in accordance with the supplemented work plan or the exceptions noted in the Preliminary Design Report submitted June 4, 1975 except that a reinforced concrete structure is designed to pass the emergency spillway and freeboard hydrographs.

The embankment is a routed fill using material from the Floodway excavation, the principal spillway inlet channel excavation and the Salt-Gila Aqueduct borrow area. The slopes are designed 2 1/2 to 1.

The reinforced concrete appurtenances are designed in accordance with NEH sections 6 and 11 and TR's 5 and 20 excluding the computer design for the conduit which was requested from the Design Unit, Washington, D.C.

The landscape features were designed by A. Wayne Smith.

## Description of Job

The job consists of 25' high earth dam approximately 4 miles long with a Type C reinforced concrete drop emergency spillway, 260 feet wide and 12' high; a 7' x 7.5' concrete box conduit with a drop inlet and SAF outlet as the principal spillway and 3 earth road ramp crossings.

## Layout

a. The horizontal alinement of the centerline of the dam is referenced to a baseline by stationing on the baseline and offset distances from it. This procedure is used to simplify the layout of the dam in a meandering pattern for aesthetic purposes. The meandering pattern is as recommended in page 4 Design Assumptions and Philosophy prepared as a part of Contract for Landscape Visual Resource Plan Contract Number AG04SCS-00045 by A. Wayne Smith and Associates, Tempe, Arizona

The storage is unaffected by the meandering embankment. Loss in storage due to offseting the dam is made up in steepening the upstream slope and in the excavation of the principal spillway inlet channel.

| | | | | |
|---|---|---|---|---|
| STATE Az | | PROJECT Buckhorn Mesa -WPP- Spook Hill FRS | | |
| A.C. | DATE 7-7-76 | CHECKED BY | DATE | JOB NO. |
| SUBJECT Road Ramp Hydrology | | | | SHEET 23 OF |

4) Storage-Indication Method

$$\bar{I} + \frac{S_1}{\Delta t} - \frac{O_1}{2} = \frac{S_2}{\Delta t} + \frac{O_2}{2}$$

$\bar{I} = \frac{I_1 + I_2}{2}$ $I$ = inflow rate $O$ = outflow rate $S$ = storage volume

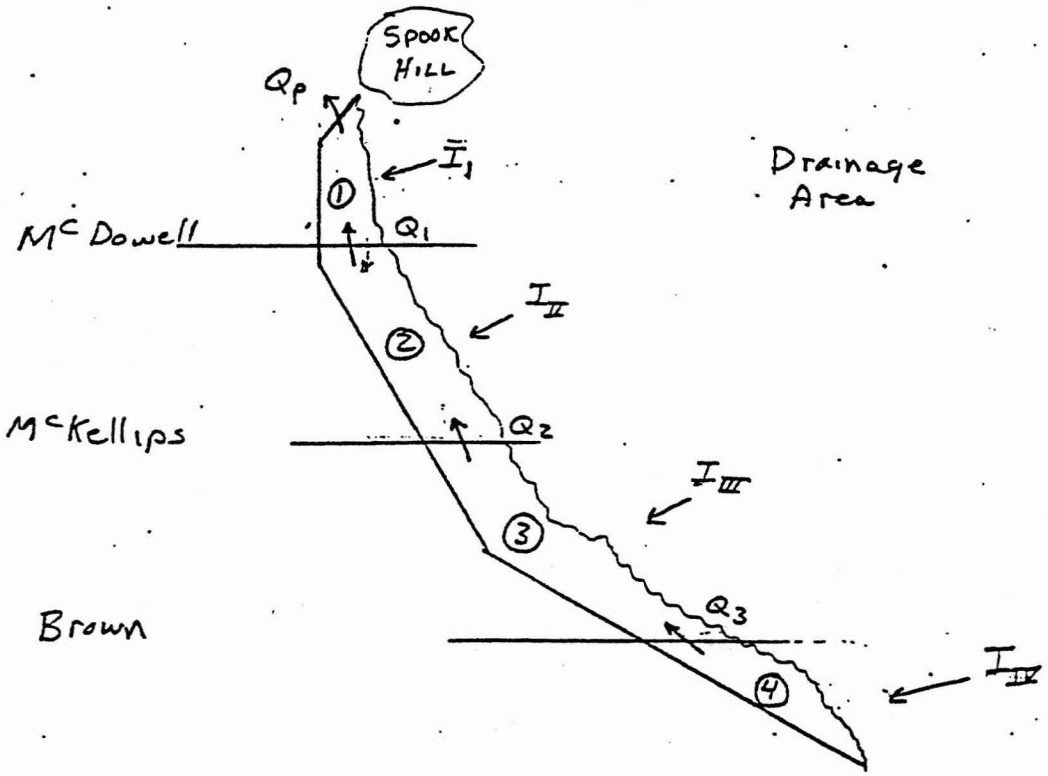
check time lag $T_t = \frac{LA}{3600q}$ $L$ = length ≃ 5,000' $A$ = end Area 1,500
$q$ = 200

$$T_t = \frac{(5000)(1500)}{3600 \quad 200} = 20.8 \text{ hrs}$$

$T_p$ = 5 days x 12 = 60

$T_t/T_p = .35 < 1/2$ – travel time delays are not serious (although a look at the routing would seem to show more like .1 to .2 days for $T_p$)

Because of the interrelationship of the four reserviors, the storage-Indication Method will require modification



| STATE | | PROJECT | | |
|---|---|---|---|---|
| ARIZONA | | BUCKHORN MESA WPP - SPOOK HILL FRS. | | |
| BY A.C. | DATE 7-6-76 | CHECKED BY | DATE | JOB NO. |
| SUBJECT | | | | SHEET 3 OF |

(A3) Principal Spillway Hydrograph

design for 10 year event (10% chance) in 1-day and 10-days
2.33" 3.73

| | | |
|---|---|---|
| 100yr - 1 day | 3.90" | Principle Spillway |
| 100 yr - 10 day | 6.10" | |
| Freeboard - | 13.0" | |

To be compatible with work done previously, the drainage areas will be factored since the total drainage area is > 10 sq mi

1 day rainfall factor = .978
10 day rainfall factor = .991

from Lew Burton 2/18/75

| Area # | Drainage Area | Area (sq mi) | Adjusted RCN | RCN | RCN (10 day) |
|---|---|---|---|---|---|
| | 14 | .25 | 75 | | |
| | 15 | .68 | 75 | | |
| (4) | 16 | 1.22 | 75 | 75 | 58 |
| | 17 | 1.44 | 75 | | |
| | 18 | 0.92 | 75 | | |
| (3) | 19 | 4.08 | 76 | 76 | 60 |
| | 20 | 1.28 | 75 | | |
| (2) | 21 | 1.91 | 76 | 77 | 61 |
| | 22 | .73 | 79 | | |
| (1) | 22 | 1.06 | 79 | 79 | 64 |

$$C_i = \frac{100\,P_a}{(T_a)^2} = \frac{100\,(8.2)}{(68.1)^2} = .174 < 1.0$$

$C_i$ is obviously less than one, therefore channel losses may be included

Channel loss factor = 0.7 (Lew Burton 2/19/75)

SCS-750-A
7-67

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Sheet 6 of ____

State ARIZONA Watershed BUCKHORN MESA Site No. 1

# PRINCIPAL SPILLWAY HYDROGRAPH

By A.C. Date 6-7-76 Ck'd ____ Date ____

| | | | Source of Data |
|---|---|---|---|
| DA 1.06 Sq. Mi. | | | |
| $T_c$ 0.6 Hrs. | | | |
| Structure Class ____ | | | |
| Design Storm Freq. 10 % | | | |
| Pa | | in. | |
| Ta | | °F | |
| Pm | | in. | |
| Tm | | °F | |
| Ci | | | |

| | | 1 Day | 10 Day | |
|---|---|---|---|---|
| (1) | Point P | " | " | |
| (2) | Areal Corr. | x ____ | x ____ | |
| (3) | Areal P | " | " | |
| (4) | CN | | | |
| (5) | Gross Q | " | " | |
| (6) | Channel Loss Factor | x ____ | x ____ | when Ci<1 |
| (7) | Net Q | " | " | |
| (8) | $Q_1/Q_{10}$ ____ " / " = | | | |
| (9) | Hydrograph Serial No. | | | |
| (10) | 1" Q | | ac. ft. | |
| (11) | DA x $Q_{10}$ ____ x ____ = | | | .59 |
| (12) | $Q_{10}$ x ac. ft./in. ____ x ____ = | | | |

| | | | | |
|---|---|---|---|---|
| (13) | Baseflow | | csm. | |
| (14) | | | in./da | (13) ÷ 26.89 |
| (15) | | | cfs | (13) x DA |
| (16) | | | ac. ft./da. | (15) x 2 |
| (17) | Minimum | | csm. | |
| (18) | | | in./da. | (17) ÷ 26.89 |
| (19) | Snowmelt | | csm. | |
| (20) | | | in./da. | (19) ÷ 26.89 |
| (21) | | | cfs | (19) x DA |
| (22) | | | ac. ft./da. | (21) x 2 |

1/ Mark out items not applicable.

| ① | ② | ③ | ④ | ⑤ |
|---|---|---|---|---|
| | ← PSMC OR PSH 1/ | | | → |
| Time (Days) | Prelim. ~~PSMC~~ PSH (cfs) | Base flow Snowmelt ( ) | Upstream Releases ( ) | Total PSMC PSH ( ) |
| | Table 21.10 x (12) or Q 10 or (11) | ① x (16) or (22) (14) or (20) (15) or (21) | | ②+③+④ |
| 0 | 0 | | | |
| .1 | .05 | | | |
| .5 | .08 | | | |
| 1.0 | .10 | | | |
| 2.0 | .13 | | | |
| 3.0 | .18 | | | |
| 3.5 | .23 | | | |
| 4.0 | .31 | | | |
| 4.2 | .49 | | | |
| 4.4 | .57 | | | |
| 4.6 | .75 | | | |
| 4.7 | .98 | | | |
| 4.8 | 1.37 | | | |
| 4.9 | 2.33 | | | |
| 5.0 | 105.62 | Sht 102 | | |
| 5.1 | 27.08 | | | |
| 5.2 | 6.54 | | | |
| 5.3 | 2.02 | | | |
| 5.4 | 1.01 | | | |
| 5.5 | .77 | | | |
| 5.6 | .54 | | | |
| 5.8 | .47 | | | |
| 6.0 | .34 | | | |
| 6.5 | .25 | | | |
| 7.0 | .19 | | | |
| 8.0 | .13 | | | |
| 9.0 | .10 | | | |
| 10.0 | .07 | | | |
| 10.1 | .00 | | | |

SCS-750-A
7-67

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Sheet 8 of ____

State ARIZONA Watershed BUCKHORN MESA Site No. 2

# PRINCIPAL SPILLWAY HYDROGRAPH

By A.C. Date 6-7-76 Ck'd ____ Date ____

| | | | Source of Data |
|---|---|---|---|
| DA 7.64 Sq. Mi. | | | |
| $T_c$ 1.0 Hrs. | | | |
| Structure Class ____ | | | |
| Design Storm Freq. 10 % | | | |
| Pa | | in. | |
| Ta | | °F | |
| Pm | | in. | |
| Tm | | °F | |
| Ci | | | |

| | | 1 Day | 10 Day | |
|---|---|---|---|---|
| (1) | Point P | " | " | |
| (2) | Areal Corr. | x ____ | x ____ | |
| (3) | Areal P | " | " | |
| (4) | CN | | | |
| (5) | Gross Q | " | " | |
| (6) | Channel Loss Factor | x ____ | x ____ | when Ci < 1 |
| (7) | Net Q | " | " | |

| | | | |
|---|---|---|---|
| (8) | $Q_1/Q_{10}$ ____ " / " = | | |
| (9) | Hydrograph Serial No. | | |

| | | | |
|---|---|---|---|
| (10) | 1" Q | | ac. ft. |
| (11) | DA x $Q_{10}$ ____ x ____ = | | 1.24 |
| (12) | $Q_{10}$ x ac. ft./in. ____ x ____ = | | |

| | | | | |
|---|---|---|---|---|
| (13) | Baseflow | | csm. | |
| (14) | | | in./da. | (13) ÷ 26.89 |
| (15) | | | cfs | (13) x DA |
| (16) | | | ac. ft./da. | (15) x 2 |
| (17) | Minimum | | csm. | |
| (18) | | | in./da. | (17) ÷ 26.89 |

| | | | | |
|---|---|---|---|---|
| (19) | Snowmelt | | csm. | |
| (20) | | | in./da. | (19) ÷ 26.89 |
| (21) | | | cfs | (19) x DA |
| (22) | | | ac. ft./da. | (21) x 2 |

1/ Mark out items not applicable.

| ① | ② | ③ | ④ | ⑤ |
|---|---|---|---|---|
| | ← PSMC OR PSH 1/ | | | → |
| Time (Days) | Prelim. ~~PSMC~~ PSH (cfs) | Base flow Snowmelt ( ) | Upstream Releases ( ) | Total PSMC PSH ( ) |
| | Table 21.10 x (12) or Q 10 or (11) | ① x (16) or (22) (14) or (20) (15) or (21) | | ②+③+④ |
| 0 | 0 | | | |
| .1 | .11 | | | |
| .5 | .17 | | | |
| 1.0 | .21 | | | |
| 2.0 | .27 | | | |
| 3.0 | .37 | | | |
| 3.5 | .48 | | | |
| 4.0 | .66 | | | |
| 4.2 | 1.04 | | | |
| 4.4 | 1.21 | | | |
| 4.6 | 1.57 | | | |
| 4.7 | 2.06 | | | |
| 4.8 | 2.87 | | | |
| 4.9 | 4.91 | | | |
| 5.0 | 221.98 | Sht 102 | | |
| 5.1 | 56.91 | | | |
| 5.2 | 13.75 | | | |
| 5.3 | 4.25 | | | |
| 5.4 | 2.11 | | | |
| 5.5 | 1.61 | | | |
| 5.6 | 1.13 | | | |
| 5.8 | 1.80 | | | |
| 6.0 | .71 | | | |
| 6.5 | .53 | | | |
| 7.0 | .39 | | | |
| 8.0 | .28 | | | |
| 9.0 | .21 | | | |
| 10.0 | .15 | | | |
| 10.1 | 0 | | | |

SCS-750-A
7-67

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Sheet 10 of ___

State ARIZONA Watershed BUCKHORN MESA Site No. 3

# PRINCIPAL SPILLWAY HYDROGRAPH

By A.C. Date 6-7-76 Ck'd ___ Date ___

| | | | Source of Data |
|---|---|---|---|
| DA 5.36 Sq. Mi. | | | |
| $T_c$ .8 Hrs. | | | |
| Structure Class ___ | | | |
| Design Storm Freq. 10% | | | |
| Pa | | in. | |
| Ta | | °F | |
| Pm | | in. | |
| Tm | | °F | |
| Ci | | | |

| | | 1 Day | 10 Day | |
|---|---|---|---|---|
| (1) | Point P | " | " | |
| (2) | Areal Corr. | x ___ | x ___ | |
| (3) | Areal P | " | " | |
| (4) | CN | | | |
| (5) | Gross Q | " | " | |
| (6) | Channel Loss Factor | x ___ | x ___ | when Ci<1 |
| (7) | Net Q | " | " | |
| (8) | $Q_1/Q_{10}$ ___ " / " = | | | |
| (9) | Hydrograph Serial No. | | | |
| (10) | 1" Q | | ac. ft. | |
| (11) | DA x $Q_{10}$ ___ x ___ = | | | 2.3 |
| (12) | $Q_{10}$ x ac. ft./in. ___ x ___ = | | | |

| | | | | |
|---|---|---|---|---|
| (13) | Baseflow | | csm. | |
| (14) | | | in./da. | (13) ÷ 26.89 |
| (15) | | | cfs | (13) x DA |
| (16) | | | ac. ft./da. | (15) x 2 |
| (17) | Minimum | | csm. | |
| (18) | | | in./da. | (17) ÷ 26.89 |

| | | | | |
|---|---|---|---|---|
| (19) | Snowmelt | | csm. | |
| (20) | | | in./da. | (19) ÷ 26.89 |
| (21) | | | cfs | (19) x DA |
| (22) | | | ac. ft./da. | (21) x 2 |

1/ Mark out items not applicable.

| ① | ② | ③ | ④ | ⑤ |
|---|---|---|---|---|
| | ← PSMC OR PSH 1/ | | | → |
| Time (Days) | Prelim. ~~PSMC~~ PSH (cfs) | Base flow Snowmelt ( )* | Upstream Releases ( ) | Total PSMC PSH ( ) |
| | Table 21.10 (12) x or Q10 or (11) | ① x (16) or (22) (14) or (20) (15) or (21) | | ②+③+④ |
| 0 | 0 | | | |
| .1 | .20 | | | |
| .5 | .32 | | | |
| 1.0 | .39 | | | |
| 2.0 | .50 | | | |
| 3.0 | .69 | | | |
| 3.5 | .90 | | | |
| 4.0 | 1.22 | | | |
| 4.2 | 1.93 | | | |
| 4.4 | 2.24 | | | |
| 4.6 | 2.92 | | | |
| 4.7 | 3.82 | | | |
| 4.8 | 5.33 | | | |
| 4.9 | 9.10 | | | |
| 5.0 | 411.74 | | | |
| 5.1 | 105.57 | Sht 103 | | |
| 5.2 | 25.50 | | | |
| 5.3 | 7.89 | | | |
| 5.4 | 3.92 | | | |
| 5.5 | 2.99 | | | |
| 5.6 | 2.09 | | | |
| 5.8 | 1.85 | | | |
| 6.0 | 1.31 | | | |
| 6.5 | .98 | | | |
| 7.0 | .72 | | | |
| 8.0 | .52 | | | |
| 9.0 | .39 | | | |
| 10.0 | .27 | | | |
| 10.1 | .01 | | | |

SCS-750-A
7-67

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Sheet 12 of ___

State ARIZONA Watershed Buckhorn Mesa Site No. 4

# PRINCIPAL SPILLWAY HYDROGRAPH

By A-C. Date 6-7-76 Ck'd ___ Date ___

| | | | Source of Data |
|---|---|---|---|
| DA 4.51 Sq. Mi. | | | |
| $T_c$ .7 Hrs. | | | |
| Structure Class | | | |
| Design Storm Freq. 10% | | | |
| Pa | | in. | |
| Ta | | °F | |
| Pm | | in. | |
| Tm | | °F | |
| Ci | | | |

| | | 1 Day | 10 Day | |
|---|---|---|---|---|
| (1) | Point P | " | " | |
| (2) | Areal Corr. | x ___ | x ___ | |
| (3) | Areal P | " | " | |
| (4) | CN | | | |
| (5) | Gross Q | " | " | |
| (6) | Channel Loss Factor | x ___ | x ___ | when Ci<1 |
| (7) | Net Q | " | " | |
| (8) | $Q_1/Q_{10}$ ___ " / " = | | | |
| (9) | Hydrograph Serial No. | | | |
| (10) | 1" Q | | ac. ft. | |
| (11) | DA x $Q_{10}$ ___ x ___ = | | | 1.71 |
| (12) | $Q_{10}$ x ac. ft./in. ___ x ___ = | | | |

| | | | | |
|---|---|---|---|---|
| (13) | Baseflow | | csm. | |
| (14) | | | in./da. | (13) ÷ 26.89 |
| (15) | | | cfs | (13) x DA |
| (16) | | | ac. ft./da. | (15) x 2 |
| (17) | Minimum | | csm. | |
| (18) | | | in./da. | (17) ÷ 26.89 |

| | | | | |
|---|---|---|---|---|
| (19) | Snowmelt | | csm. | |
| (20) | | | in./da. | (19) ÷ 26.89 |
| (21) | | | cfs | (19) x DA |
| (22) | | | ac. ft./da. | (21) x 2 |

1/ Mark out items not applicable.

| ① Time (Days) | ② ← PSMC OR PSH 1/ → Prelim. ~~PSMC~~ PSH (cfs) | ③ Base flow Snowmelt ( ) | ④ Upstream Releases ( ) | ⑤ Total PSMC PSH ( ) |
|---|---|---|---|---|
| | Table 21.10 (12) x or Q 10 or (11) | ① x (16) or (22) (14) or (20) (15) or (21) | | ②+③+④ |
| 0 | | | | |
| .1 | .15 | | | |
| .5 | .24 | | | |
| 1.0 | .29 | | | |
| 2.0 | .37 | | | |
| 3.0 | .52 | | | |
| 3.5 | .67 | | | |
| 4.0 | .91 | | | |
| 4.2 | 1.43 | | | |
| 4.4 | 1.67 | | | |
| 4.6 | 2.17 | | | |
| 4.7 | 2.84 | | | |
| 4.8 | 3.96 | | | |
| 4.9 | 6.76 | | | |
| 5.0 | 306.12 | Sht 104 | | |
| 5.1 | 78.49 | | | |
| 5.2 | 18.96 | | | |
| 5.3 | 5.87 | | | |
| 5.4 | 2.91 | | | |
| 5.5 | 2.22 | | | |
| 5.6 | 1.55 | | | |
| 5.8 | 1.38 | | | |
| 6.0 | .97 | | | |
| 6.5 | .73 | | | |
| 7.0 | .54 | | | |
| 8.0 | .38 | | | |
| 9.0 | .29 | | | |
| 10.0 | .20 | | | |
| 10.1 | .01 | | | |

| STATE Az | | PROJECT Buckhorn Mesa WPP - Spook Hill FRS | | |
|---|---|---|---|---|
| BY A.C. | DATE 7-12-76 | CHECKED BY | DATE | JOB NO. |
| SUBJECT Road Ramp Hydrology | | | | SHEET 20 OF |

| Time (days) | I (cfs) | $S_2/\Delta t + O_2/2$ (cfs) | $O_2$ (cfs) | S (Ac-ft) | Elev. (MSL-ft) |
|---|---|---|---|---|---|
| 4.9 | 2.33 | 12.61 | 0 | 2.5 | 1576.79 |
| 5.0 | 105.62 | 118.23 | 66 | (not needed) | 1578.15 (from Sheet 12) |
| 5.1 | 27.08 | 79.31 | 33.5 | | 1577.88 |

Begin with Known storage value with $O_2$

Maximum elevation 1578.15 of Reservior 1

(A5)

This is now the tailwater condition on the outflow from reservior 2

| Elev. | S | S/Δt | $O_2$ | $S/\Delta t + O_2/2$ |
|---|---|---|---|---|
| 1577 | 13.8 | 69.6 | 0 | 69.6 |
| 1578 | 53.0 | 267.3 | 0 | 267.3 |
| 1578.3 | 65.0 | 327.8 | 93 | 374.3 |
| 1578.5 | 75.0 | 378.2 | 157 | 456.7 |
| 1578.2 | 60.5 | 305.1 | 45 | 327.6 |
| 1579 | 102.0 | 514.4 | 316 | 672.4 |
| 1580 | 160 | 806.9 | too high | |

(A6)

| Time (days) | I (cfs) | $S_2/\Delta t + O_2/2$ (cfs) | $O_2$ (cfs) | Elev (MSL ft) | S (Ac-ft) |
|---|---|---|---|---|---|
| 4.9 | 4.91 | 26.37 | 0 | 1576.72 | 5.23 |
| 5.0 | 221.98 | 248.35 | 0 | ? | |
| 5.1 | 56.91 | 305.26 | 20 | (extrapolated) 1578.17 | |
| 5.2 | 13.75 | 299.01 | 15 | 1578.16 | |

Max. elevation 1578.16 of Reservior 2

This is now the tailwater condition on the outflow from reservior 3

| STATE Az | | PROJECT Buckhorn Mesa WPP Spook Hill FRS | | |
|---|---|---|---|---|
| BY A.C. | DATE 7-12-76 | CHECKED BY | DATE | JOB NO. |
| SUBJECT Road Ramp Hydrology | | | | SHEET 21 OF |

Reservior 3

| Elev. | S | S/Δt | $O_2$ | $S/\Delta t + O_2/2$ |
|---|---|---|---|---|
| 1577 | 17.5 | 88.3 | 0 | 88.3 |
| 1578 | 65 | 327.8 | 0 | 327.8 |
| 1578.2 | 78 | 393.3 | 40 | 413.3 |
| 1578.5 | 94 | 474.0 | 155 | 551.5 |
| 1579 | 129 | 650.5 | 252 | 776.5 |

| Time (days) | I (cfs) | $S_2/\Delta t + O_2/2$ (cfs) | $O_2$ (cfs) | Elev. (MSL-ft) | S (Ac-ft) |
|---|---|---|---|---|---|
| 4.9 | – | 48.97 | 0 | 1577.70 | 9.71 |
| 5.0 | 411.74 | 460.7 | 42 | 1578.20 | – |
| 5.1 | 105.57 | 524.28 | 43 | 1578.20 | |
| 5.2 | 25.50 | 506.78 | 42.5 | 1578.20 | |

Sht 10

Max. elevation of Reservior 3 is 1578.20

Reservior 4

| Elev. | S | S/Δt | $O_2$ | $S/\Delta t + O_2/2$ |
|---|---|---|---|---|
| 1578 | 18.5 | 93.3 | 0 | |
| 1578.2 | 22.0 | 110.9 | 0 | |
| 1578.3 | 25.0 | 126.1 | 72 | 162.1 |
| 1578.5 | 28.0 | 141.2 | 143 | 212.7 |
| 1579 | 38.5 | 194.2 | 245 | 316.7 |
| 1579.5 | 50.0 | 252.1 | 310 | 407.1 |
| 1580.0 | | | | |

| STATE | | PROJECT | | |
|---|---|---|---|---|
| Az. | | Buckhorn Mesa WPP- Spook Hill FRS | | |
| BY A-C | DATE 7-12-76 | CHECKED BY | DATE | JOB NO. |
| SUBJECT Road Ramp Hydrology | | | | SHEET 22 OF |

Reservior 4

| Time | I | $S_2/\Delta t + O_2/2$ | $O_2$ | Elev. | S |
|---|---|---|---|---|---|
| 4.9 | — | 36.41 | 0 | 1577.20 | 7.22 |
| 5.0 | 306.12 | 342.53 | 262 | 1579.12 | — |
| 5.1 | 78.49 | 159.02 | 64 | 1578.28 | — |

Max. elevation of reservior 4 is 1579.12

| | | Reservior | |
|---|---|---|---|
| Maximum elevation | 1578.15 | 1 | |
| | 1578.16 | 2 | McDowell Road (now at 1580.7) |
| | 1578.20 | 3 | McKellips Road (now at 1582.1) |
| | 1579.12 | 4 | Brown Road |

| STATE Az | | PROJECT Buckhorn Mesa WPP - Spook Hill FRS | | |
|---|---|---|---|---|
| BY A.C. | DATE 7-26-76 | CHECKED BY | DATE | JOB NO. 2005 |
| SUBJECT Road Ramp Hydrology | | | | SHEET 27 OF |

Comparison of two methods

| reservior | Robin's short cut | Reservior Balancing | Difference |
|---|---|---|---|
| 1 | 1578.15 | 1578.40 | -.35 |
| 2 | 1578.16 | 1578.55 | -.39 |
| 3 | 1578.20 | 1578.71 | -.51 |
| 4 | 1579.12 | 1578.87 | +.25 |

Several conditions effect the relative results.

1. There is continual flow between reserviors
2. flow can be in either direction
3. Storage volume v.s. drainage area for set elevations vary
4. a flash flood condition exists.

The short cut method has usable applications. It would seem that it would give conservative results for a two reservior system (one road ramp). If a realistic base flow figure could be added to simulate flow between reserviors, then the method may be useable for a series of reserviors.

The following road elevations will be used

McDowell Road. - 1578.7

McKellips Road - 1578.8

Brown Road - 1579.0

| STATE | | PROJECT | | |
|---|---|---|---|---|
| Az | | Buckhorn Mesa WPP - Spook Hill F.R.S. | | |
| BY A.C. | DATE 8-2-76 | CHECKED BY | DATE | JOB NO. 2005 |
| SUBJECT Freeboard Design - Road Ramps | | | | SHEET 1 OF |

The road ramps have been designed. The next step is determining the maximum elevation of the top of the dam. It is hoped that the road ramps will not cause headlosses that will cause overtopping up stream.

Cross sections at Road Ramps (⊥ to dam, not along road) from ℄

Brown Road

| Natural Ground offset | Natural Ground Elev. | Road Ramp offset | Road Ramp Elev. |
|---|---|---|---|
| 0 | 1575 | 0 | 1591 |
| 100 | 1576 | 150 | 1590 |
| 210 | 1578 | 250 | 1582 |
| 300 | 1580 | 290 | 1580.25 |
| 520 | 1582 | 440 | 1580.25 |
| 610 | 1584 | 520 | 1582 |
| 680 | 1586 | 610 | 1584 |
| 770 | 1588 | 680 | 1586 |
| 860 | 1590 | 770 | 1588 |
| 950 | 1592 | 860 | 1590 |
| | | 950 | 1592 |

McKellips Road

| offset | Elev. |
|---|---|
| 0 | (1592) |
| 140 | 1591 |
| 240 | 1589.7 |
| 390 | 1582.3 |
| 510 | 1579.7 |
| 670 | 1579.7 |
| 755 | 1580.8 |
| 1000 | 1589.0 |
| 1080 | 1590.0 |
| 1300 | 1592.0 |

McDowell Road

| offset | Elev. |
|---|---|
| 200 | 1591.25 |
| 300 | 1589.8 |
| 450 | 1582.6 |
| 550 | 1579.6 |
| 670 | 1579.6 |
| 790 | 1582.8 |
| 815 | 1589.8 |
| 915 | 1592 |

| STATE Arizona | | PROJECT Buckhorn Mesa W.F.S. - Spook Hill F.R.S. | | |
|---|---|---|---|---|
| BY Fuller | DATE 2/18/75 | CHECKED BY ATW | DATE 4/75 | JOB NO. 2005 |
| SUBJECT Hydrology - Principal Spillway Routing | | | | SHEET ___ OF ___ |

Determine 100 Yr - 24 Hr & 100 Yr 10 day Precipitation Values to be used in principal spillway routing.

Point Precipitation values from calculations by R.M.B., May 30, 1973

100 Yr 24 hr. = 3.90 inches

100 Yr 10 day = 6.10 inches

Trip report 9/10/74

Estimate Areal Reduction Factors for drainage area = 13.57 mi²

Fig. A-1 T.N. PO-6 — 100 Yr 24 Hr Reduction Factor = 0.978

Table 21.1 NEH-4 — 100 Yr 10 day Reduction Factor = 0.995

∴ 100 Yr 24 hr Areal Rainfall = (3.90)(.978) = 3.81 in.

100 Yr 10 day Areal Rainfall = (6.10)(.995) = 6.07 in.

# Appendix B3

# Inspection Report

# PHASE I INSPECTION REPORT

FOR

SPOOK HILL RETARDING DAM
I.D. NO. AZ00175
MARICOPA COUNTY, ARIZONA

NATIONAL PROGRAM

FOR INSPECTION OF DAMS

Prepared for

THE STATE OF ARIZONA
DEPARTMENT OF WATER RESOURCES

by

ERTEC WESTERN, INC.
Phoenix, Arizona

August 1981

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2711
LOS ANGELES, CALIFORNIA 90053

SPLED-DA

10 September 1981

Mr. Wesley E. Steiner
Director
Arizona Department of Water Resources
99 East Virginia Avenue, Suite 150
Phoenix, Arizona 85004

Dear Mr. Steiner:

We have reviewed and approved the Phase I Inspection Report (dated August 1981) for Spook Hill Retarding Dam. A copy of this letter and the approved report should be provided to the owner.

Sincerely,

PAUL W. TAYLOR
Colonel, CE
Commanding

Copy Furnished:
Mr. Thomas G. Rockenbaugh
State Conservationist
U.S. Department of Agriculture
Soil Conservation Service
Federal Building, Room 3008
Phoenix, Arizona 85025
with copy of report

1981 Computations

Table 6.1.—General-storm PMP computations for the Colorado River and Great basin

Drainage [illegible] Area 11.3 $mi^2$ ~~($km^2$)~~

Latitude [illegible], Longitude [illegible] of basin center

Month Aug

| Step | Duration (hrs) 6 | 12 | 18 | 24 | 48 | 72 |
|---|---|---|---|---|---|---|
| **A. Convergence PMP** | | | | | | |
| 1. Drainage average value from one of figures 2.5 to 2.16 | 14 in. ~~(mm)~~ | | | | | |
| 2. Reduction for barrier-elevation [fig. 2.18] | 80% | | | | | |
| 3. Barrier-elevation reduced PMP [step 1 X step 2] | 11.2 in. ~~(mm)~~ | | | | | |
| 4. Durational variation [figs. 2.25 to 2.27 and table 2.7]. | 76 | 90 | 96 | 100 | 111 | 115% |
| 5. Convergence PMP for indicated durations [steps 3 X 4] | 8.5 | 10.1 | 10.8 | 11.2 | 12.4 | 12.9 in. ~~(mm)~~ |
| 6. Incremental 10 $mi^2$ (26 $km^2$) PMP [successive subtraction in step 5] | 8.5 | 1.6 | 0.7 | 0.4 | 1.2 | 0.5 in. ~~(mm)~~ |
| 7. Areal reduction [select from figs. 2.28 and 2.29] | 99 | 100 | 100 | 100 | 100 | 100% |
| 8. Areally reduced PMP [step 6 X step 7] | 8.4 | 1.6 | 0.7 | 0.4 | 1.2 | 0.5 in. ~~(mm)~~ |
| 9. Drainage average PMP [accumulated values of step 8] | 8.4 | 10.0 | 10.7 | 11.1 | 12.3 | 12.8 in. ~~(mm)~~ |
| **B. Orographic PMP** | | | | | | |
| 1. Drainage average orographic index from figure 3.11a to d. | 3.1 in. ~~(mm)~~ | | | | | |
| 2. Areal reduction [figure 3.20] | 100% | | | | | |
| 3. Adjustment for month [one of figs. 3.12 to 3.17] | 120% | | | | | |
| 4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3] | 3.[illegible] in. ~~(mm)~~ | | | | | |
| 5. Durational variation [table 3.6] | 36 | 63 | 84 | 100 | 139 | 157% |
| 6. Orographic PMP for given durations [steps 4 X 5] | 1.1 | 2.0 | 2.6 | 3.1 | 4.3 | 4.9 in. ~~(mm)~~ |
| **C. Total PMP** | | | | | | |
| 1. Add steps A9 and B6 | 9.5 | 12.0 | 13.3 | 14.2 | 16.6 | 17.7 in. ~~(mm)~~ |

2. PMP for other durations from smooth curve fitted to plot of computed data.

3. Comparison with local-storm PMP (see sec. 6.3).

1981 Computations

Table 6.3A.—Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Spook Hill Area _____ $mi^2$ ($km^2$)
Latitude 35°07' Longitude 114°20' Minimum Elevation 1600 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-$mi^2$ (2.6-$km^2$) PMP for drainage [fig. 4.5]. 11.6 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. 100 %

   b. Multiply step 1 by step 2a. 11.6 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.25

| | Duration (hr) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1/4 | 1/2 | 3/4 | 1 | 2 | 3 | 4 | 5 | 6 |
| 4. Durational variation for 6/1-hr ratio of step 3 [table 4.4]. | 74 | 89 | 95 | 100 | 112 | 118 | 121 | 123 | 125 % |
| 5. 1-$mi^2$ (2.6-$km^2$) PMP for indicated durations [step 2b X step 4]. | 8.6 | 10.3 | 11.0 | 11.6 | 13.0 | 13.7 | 14.0 | 14.3 | 14.5 in. ~~(mm)~~ |
| 6. Areal reduction [fig. 4.9]. | 72 | 78 | 80 | 82 | 84 | 85 | 86 | 87 | 88 % |
| 7. Areal reduced PMP [steps 5 X 6]. | 6.2 | 8.0 | 8.8 | 9.5 | 10.9 | 11.7 | 12.0 | 12.4 | 12.8 in. ~~(mm)~~ |
| 8. Incremental PMP [successive subtraction in step 7]. | | | | 9.5 | 1.4 | 0.8 | 0.3 | 0.4 | 0.4 in. ~~(mm)~~ |
| | | | | 6.2 | 1.8 | 0.8 | 0.7 | | } 15-min. increments |

9. Time sequence of incremental PMP according to:

   Hourly increments [table 4.7]. 0.3 0.4 1.4 9.5 0.8 0.4 in. (mm)

   Four largest 15-min. increments [table 4.8]. 6.2 1.8 0.8 0.7 in. ~~(mm)~~

# APPENDIX C

## Supporting Hydrologic Calculations

# Appendix C1

# Probable Maximum Precipitation

**Table C.1 TR-20 Rainfall Distribution**

| Time | | Rainfall | Time | | Rainfall |
|---|---|---|---|---|---|
| (min) | (hr) | Distribution | (min) | (hr) | Distribution |
| 0.0 | 0.0 | 0.000 | 180.0 | 3.0 | 0.815 |
| 7.2 | 0.1 | 0.002 | 187.2 | 3.1 | 0.837 |
| 14.4 | 0.2 | 0.005 | 194.4 | 3.2 | 0.853 |
| 21.6 | 0.4 | 0.008 | 201.6 | 3.4 | 0.867 |
| 28.8 | 0.5 | 0.011 | 208.8 | 3.5 | 0.880 |
| 36.0 | 0.6 | 0.015 | 216.0 | 3.6 | 0.892 |
| 43.2 | 0.7 | 0.019 | 223.2 | 3.7 | 0.903 |
| 50.4 | 0.8 | 0.024 | 230.4 | 3.8 | 0.913 |
| 57.6 | 1.0 | 0.030 | 237.6 | 4.0 | 0.922 |
| 64.8 | 1.1 | 0.036 | 244.8 | 4.1 | 0.930 |
| 72.0 | 1.2 | 0.042 | 252.0 | 4.2 | 0.938 |
| 79.2 | 1.3 | 0.050 | 259.2 | 4.3 | 0.945 |
| 86.4 | 1.4 | 0.058 | 266.4 | 4.4 | 0.951 |
| 93.6 | 1.6 | 0.068 | 273.6 | 4.6 | 0.957 |
| 100.8 | 1.7 | 0.078 | 280.8 | 4.7 | 0.962 |
| 108.0 | 1.8 | 0.088 | 288.0 | 4.8 | 0.967 |
| 115.2 | 1.9 | 0.100 | 295.2 | 4.9 | 0.972 |
| 122.4 | 2.0 | 0.125 | 302.4 | 5.0 | 0.975 |
| 129.6 | 2.2 | 0.175 | 309.6 | 5.2 | 0.978 |
| 136.8 | 2.3 | 0.235 | 316.8 | 5.3 | 0.982 |
| 144.0 | 2.4 | 0.300 | 324.0 | 5.4 | 0.985 |
| 151.2 | 2.5 | 0.380 | 331.2 | 5.5 | 0.987 |
| 158.4 | 2.6 | 0.470 | 338.4 | 5.6 | 0.991 |
| 165.6 | 2.8 | 0.575 | 345.6 | 5.8 | 0.994 |
| 172.8 | 2.9 | 0.695 | 352.8 | 5.9 | 0.997 |
| | | | 360.0 | 6.0 | 1.000 |

Notes:

1. This data was presented in the Evaluation of Preliminary Design Report (1975) by using a dimensionless time increment of 0.02.
2. The RAINFL card, Table No. 2, can be found in the Evaluation Report.
3. The storm duration (6 hr) is multiplied by the dimensionless time increment (0.02) to compute the actual time increment (7.2 min) of the rainfall distribution.
4. This is a typical application for Emergency Spillway and Freeboard Design (see TR-20 manual, Appendix G, Table #6).

**Table C.2 General PMP**

| | | | Duration (hrs) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 6 | 12 | 18 | 24 | 48 | 72 |
| | | | | | | | | |
| | **Steps:** | | | | | | | |
| | | | | | | | | |
| **A.** | **Convergence PMP** | | | | | | | |
| | 1. Drainage average value (in) (Fig. 2.12) | 14.1 | | | | | | |
| | 2. Reduction for barrier elevation (Fig. 2.18) | 83% | | | | | | |
| | 3. Barrier-Elevation reduced PMP (in) (Step 1 x Step 2) | 11.7 | | | | | | |
| | 4. Durational variation (Fig. 2.26 and Table 2.7) | | 76% | 90% | 96% | 100% | 111% | 115% |
| | 5. Convergence PMP for indicated durations (Steps 3 x 4) | | 8.9 | 10.5 | 11.2 | 11.7 | 13.0 | 13.5 |
| | 6. Incremental 10 mi^2 (26 km^2) PMP (successive subtraction in Step 5) | | 8.9 | 1.6 | 0.7 | 0.5 | 1.3 | 0.5 |
| | 7. Area reduction (Fig. 2.29) | | 99% | 100% | 100% | 100% | 100% | 100% |
| | 8. Areally reduced PMP (step 6 x step 7) | | 8.8 | 1.6 | 0.7 | 0.5 | 1.3 | 0.5 |
| | 9. Drainage average PMP (accumulated values of step 8) | | 8.8 | 10.4 | 11.1 | 11.6 | 12.9 | 13.4 |
| | | | | | | | | |
| **B.** | **Orographic PMP** | | | | | | | |
| | 1. Drainage Average orographic index (in) (Fig. 3.11d) | 3.8 | | | | | | |
| | 2. Area reduction (Fig. 3.20) | 99% | | | | | | |
| | 3. Adjustment for month (Fig. 3.15) | 100% | | | | | | |
| | 4. Areally and seasonally adjusted PMP (steps 1 x 2 x 3) | 3.8 | | | | | | |
| | 5. Durational variation (Table 3.9) | | 36% | 63% | 84% | 100% | 141% | 159% |
| | 6. Orographic PMP for given durations (steps 4 x 5) | | 1.4 | 2.4 | 3.2 | 3.8 | 5.4 | 6.0 |
| | | | | | | | | |
| **C.** | **Total PMP** | | | | | | | |
| | 1. Add steps A9 and B6 | | 10.2 | 12.8 | 14.3 | 15.4 | 18.3 | 19.4 |
| | 2. Incremental PMP | | | | | 15.4 | 2.9 | 1.1 |
| | | | 10.2 | 2.6 | 1.5 | 1.1 | | |

Notes:
1. Latitude: 33 27, Longitude: 111 38 of basin center
2. Area: 13.0 mi^2
3. Precipitation depths are computed by using the procedures and guidelines in HMR 49 (1977)
4. See Table C.4 for General PMP distribution

Latitude : 33° 27' North
Longitude : 111° 38' West

≈ 33.45°
Spook Hill Retarding Dam
≈ 111.63°

Convergence
PMP



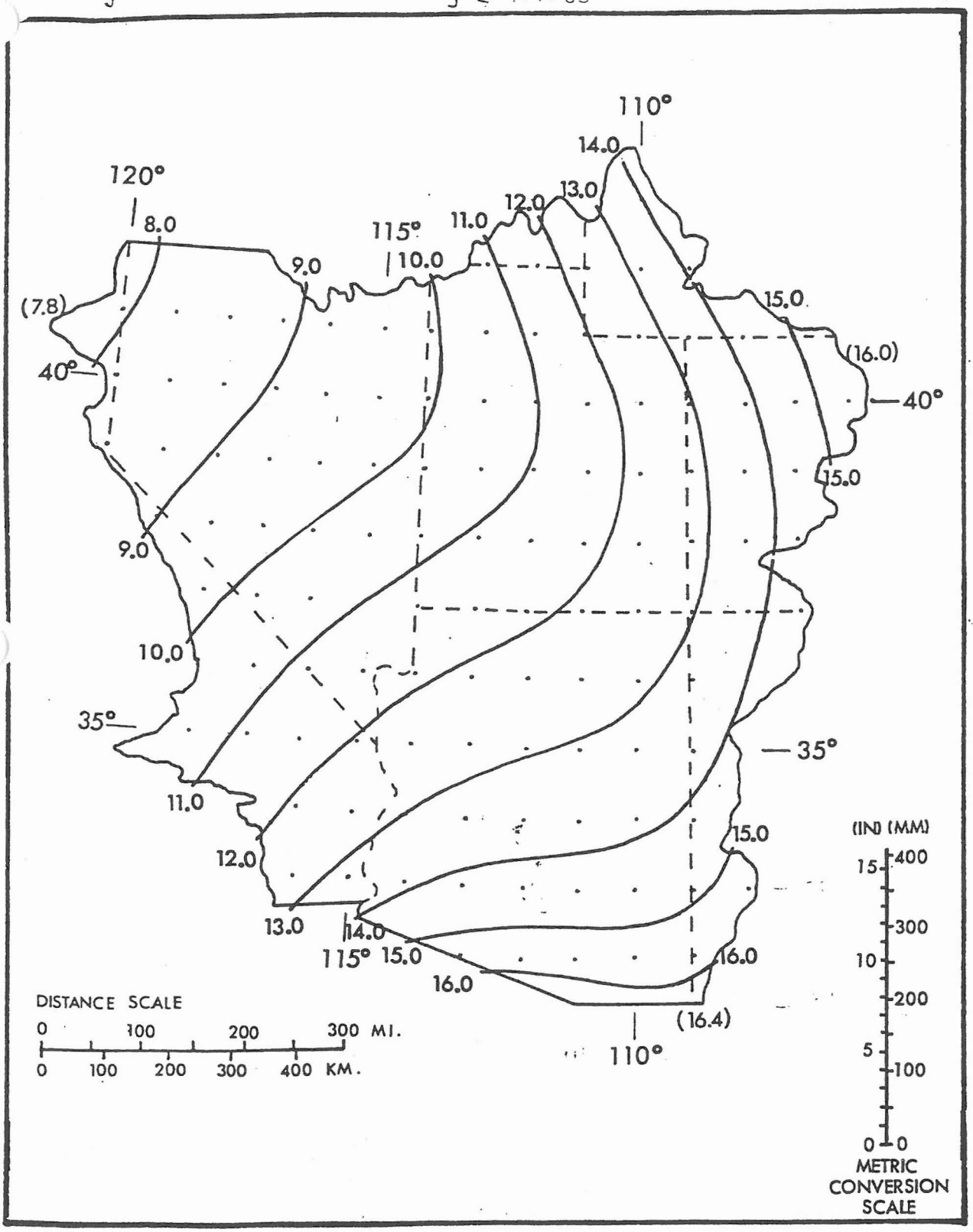



*Figure 2.12.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi$^2$ (26 km$^2$) for August. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.*

PMP = 14.1"

14.0 (1981)

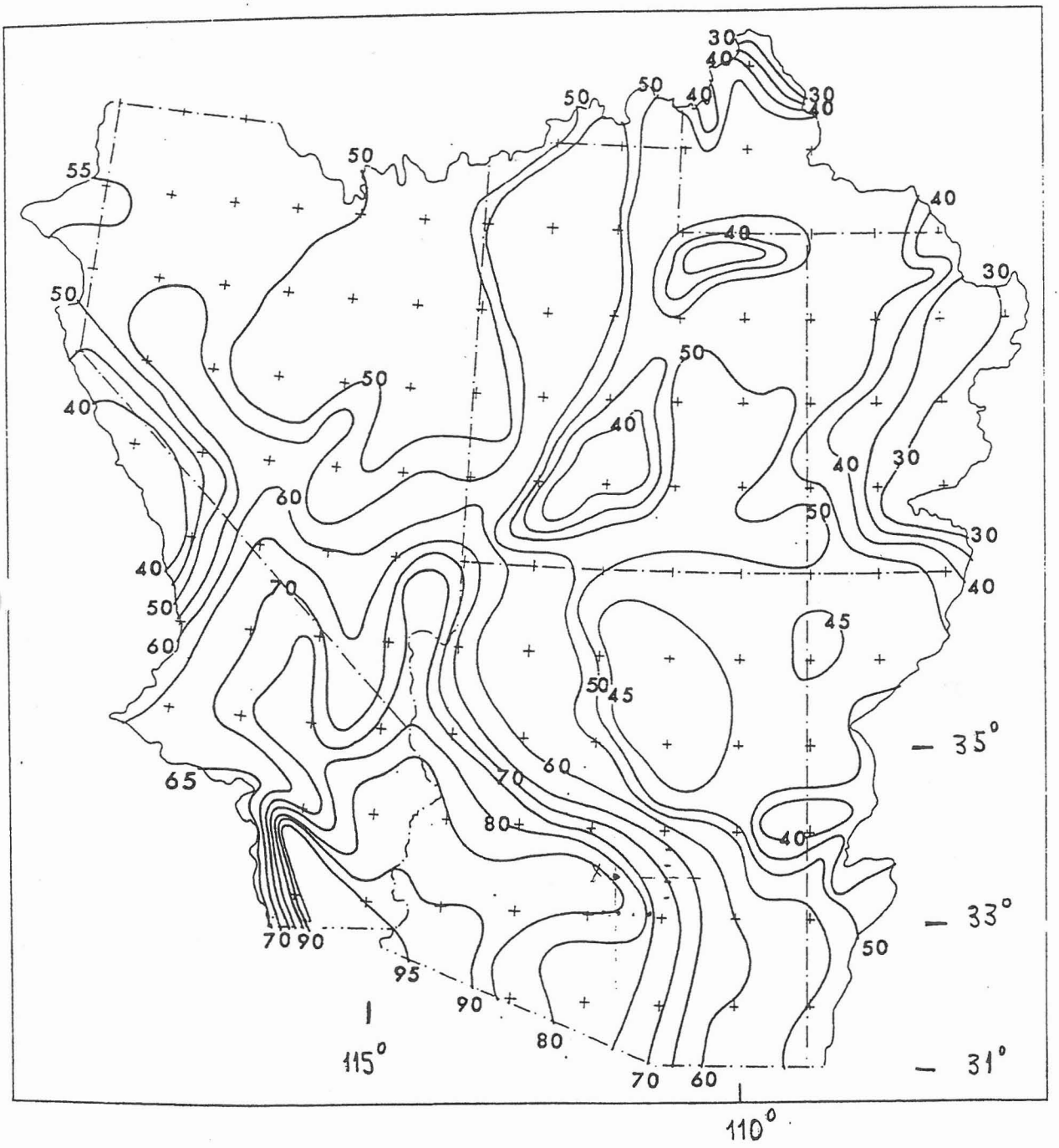
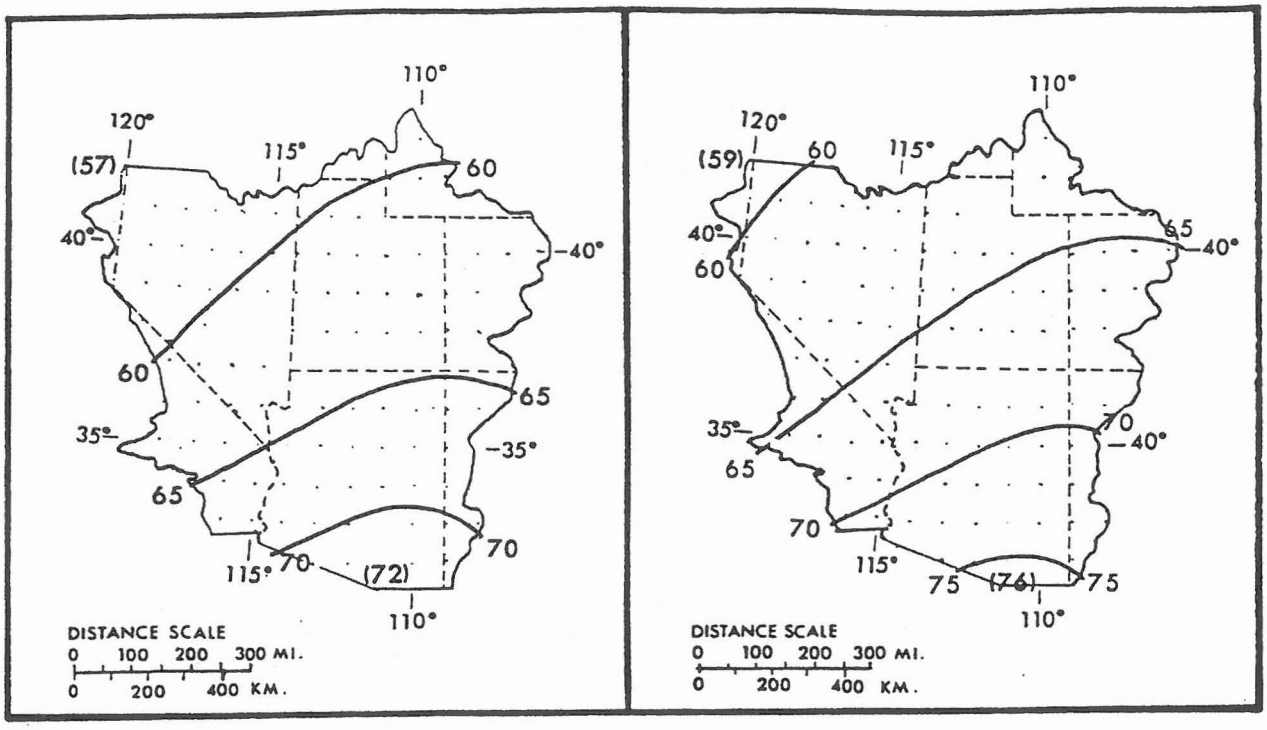



*Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.*

Percent of 1000-mb convergence PMP = 83%

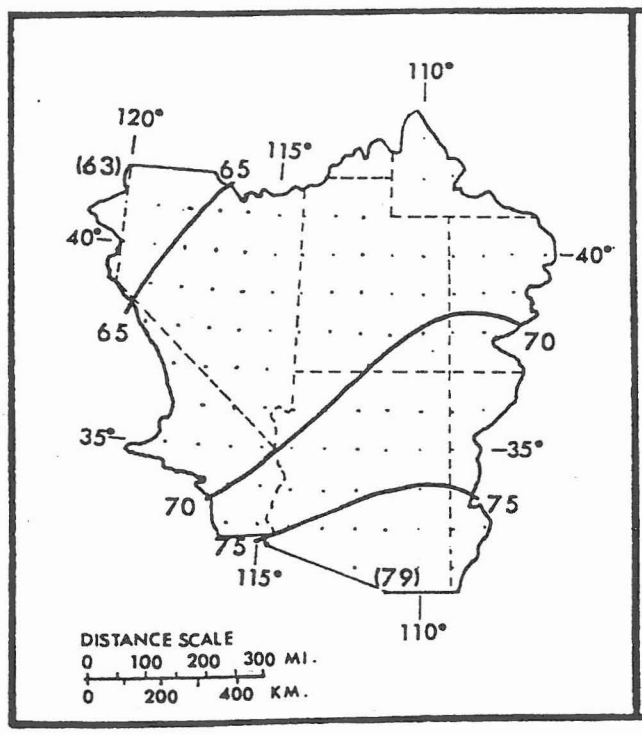
80% (1981)



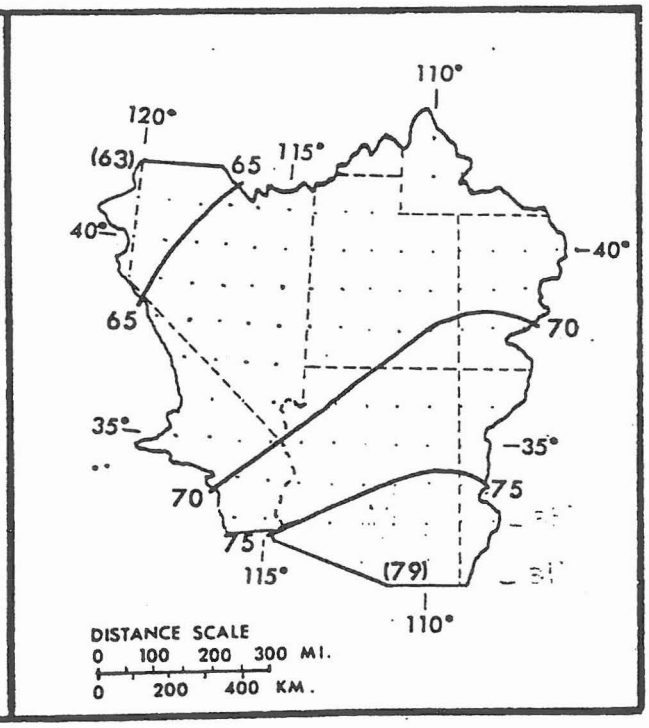

*May*




*June*




*July*




*August*

*Figure 2.26.--Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.*

Durational Variation = 76%

76% (1981)

For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

Table 2.7.--Durational variation of convergence PMP (in percent of 24-hr amount).

| Duration (Hrs) | | | | | | Duration (Hrs) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 12 | 18 | 24 | 48 | 72 | 6 | 12 | 18 | 24 | 48 | 72 |
| 50 | 76 | 90 | 100 | 129 | 150 | 66 | 84 | 93 | 100 | 116 | 124 |
| 51 | 77 | 90 | 100 | 128 | 148 | 67 | 85 | 94 | 100 | 116 | 123 |
| 52 | 77 | 90 | 100 | 127 | 146 | 68 | 85 | 94 | 100 | 115 | 122 |
| 53 | 77 | 91 | 100 | 127 | 144 | 69 | 86 | 94 | 100 | 115 | 121 |
| 54 | 78 | 91 | 100 | 126 | 142 | | | | | | |
| 55 | 78 | 91 | 100 | 125 | 140 | 70 | 87 | 94 | 100 | 114 | 120 |
| 56 | 79 | 91 | 100 | 124 | 138 | 71 | 87 | 95 | 100 | 114 | 119 |
| 57 | 79 | 92 | 100 | 123 | 137 | 72 | 88 | 95 | 100 | 113 | 118 |
| 58 | 80 | 92 | 100 | 122 | 135 | 73 | 88 | 95 | 100 | 113 | 118 |
| 59 | 80 | 92 | 100 | 121 | 134 | 74 | 89 | 95 | 100 | 112 | 117 |
| | | | | | | 75 | 89 | 96 | 100 | 112 | 116 |
| 60 | 81 | 92 | 100 | 120 | 132 | 76 | 90 | 96 | 100 | 111 | 115 |
| 61 | 81 | 92 | 100 | 120 | 131 | 77 | 90 | 96 | 100 | 110 | 114 |
| 62 | 82 | 93 | 100 | 119 | 129 | 78 | 91 | 96 | 100 | 110 | 114 |
| 63 | 82 | 93 | 100 | 118 | 128 | 79 | 92 | 97 | 100 | 109 | 113 |
| 64 | 83 | 93 | 100 | 117 | 126 | | | | | | |
| 65 | 84 | 93 | 100 | 117 | 125 | 80 | 92 | 97 | 100 | 109 | 113 |

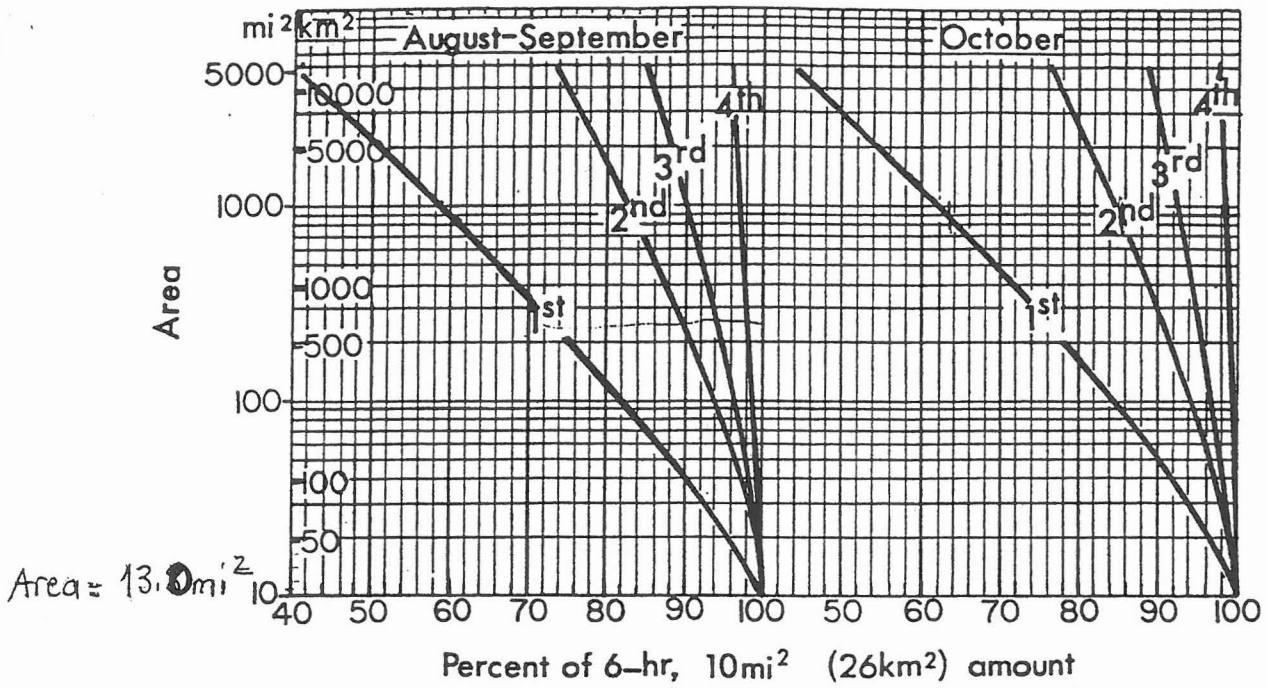
Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

## 2.5 Areal Reduction for Basin Size

For operational use, basin average values of convergence PMP are needed rather than 10-mi$^2$ (26-km$^2$) values. Preferably, the method for reducing 10-mi$^2$ (26-km$^2$) values to basin average rainfalls should be derived from depth-area relations of storms in the region. However, all general storms in the region include large proportions of orographic precipitation.

Our solution was to use generalized depth-area relations developed for PMP estimates within bordering zones in the Central and Eastern United States (Riedel et al. 1956). The smoothed areal variations adopted for the Southwestern States are shown in figures 2.28 and 2.29 for each month or a combination of months where differences are insignificant.

Figures 2.28 and 2.29 give depth-area relations that reduce 10-mi$^2$ (26-km$^2$) convergence PMP for basin sizes up to 5,000 mi$^2$ (12,950 km$^2$) for each month. Areal variations are given for the 4 greatest (1st to 4th) 6-hr PMP increments. After the 4th increment no reduction for basin size is required. Application of these figures will become clear through consideration of an example of PMP computation in chapter 6.



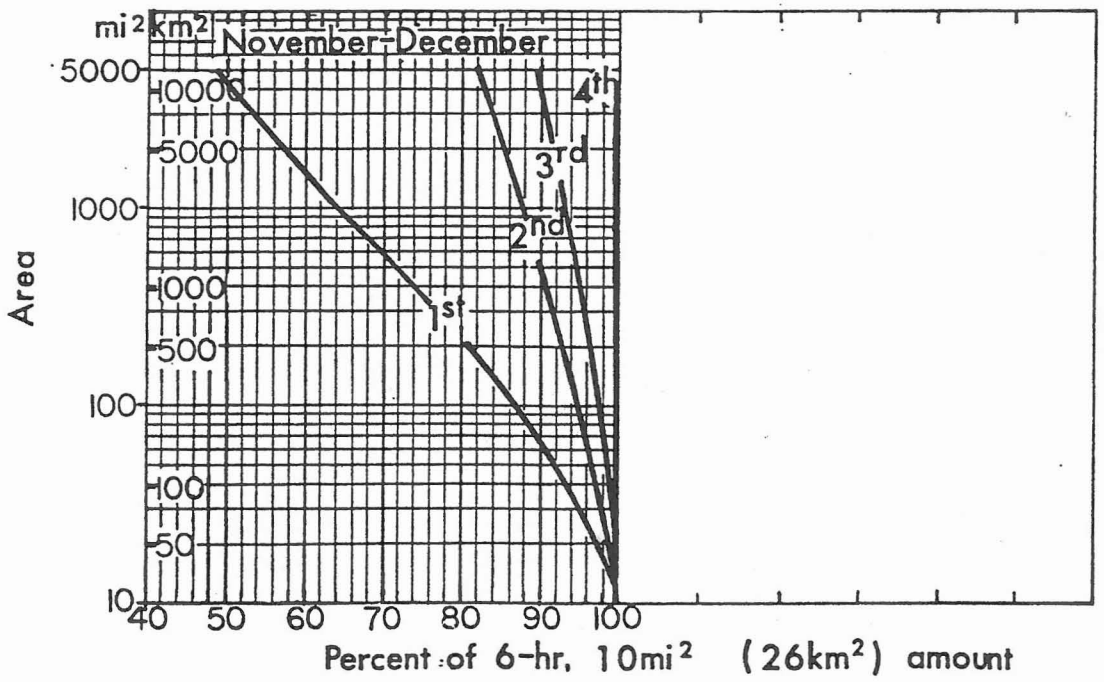




*Figure 2.29.--Depth-area variation for convergence PMP for first to fourth 6-hr increments.*

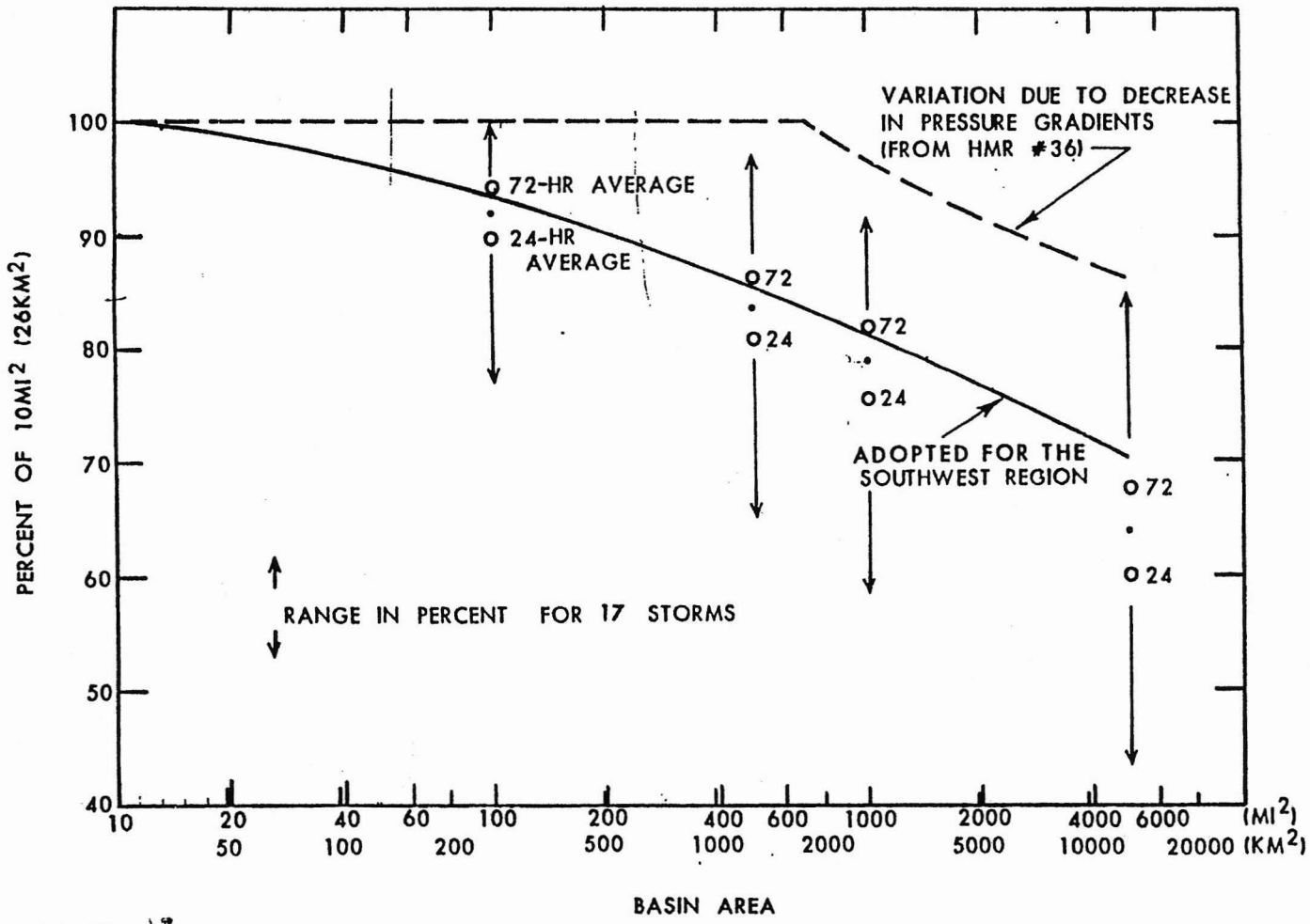
Duration (hrs)

| 6 | 12 | 18 | 24 | 48 | 72 | |
|---|---|---|---|---|---|---|
| 99% | 100 | 100 | 100 | 100 | 100 | |
| 99% | 100 | 100 | 100 | 100 | 100 | (1981) |

Orographic - TMP

FIGURE 3.11d.—10-mi$^2$ (26-km$^2$) 24-hr orographic PMP index map (inches), southern section.

Orographic Index = 3.8 in



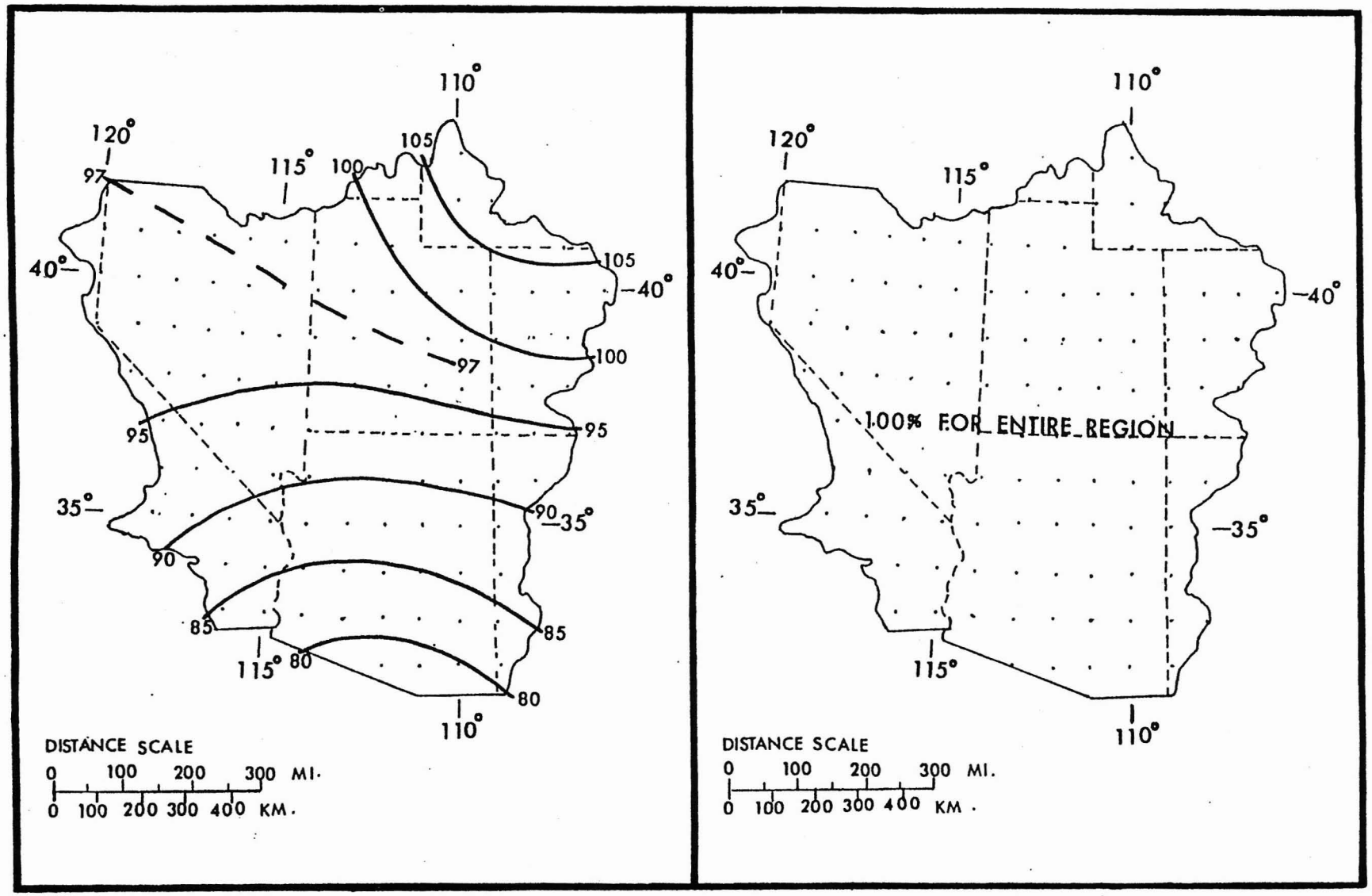

Area = 13.8 mi²

Area = 11.3 mi² (1981)

*Figure 3.20.--Variation of orographic PMP with basin size.*

Areal Reduction = 99% ✓

100% (1981)




*July* *August*

*Figure 3.15.--Seasonal variation in 10-mi$^2$ (26-km$^2$) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).*

Adjustment for month = 100%

Table 3.9.--Durational variation of orographic PMP

| Latitude °N | Percent of 24-hr value | | | | | |
|---|---|---|---|---|---|---|
| | 6 hr | 12 | 18 | 24 | 48 | 72 |
| 42 | 28 | 55 | 79 | 100 | 161 | 190 |
| 41 | 29 | 56 | 79 | 100 | 160 | 189 |
| 40 | 30 | 57 | 80 | 100 | 159 | 187 |
| 39 | 30 | 57 | 80 | 100 | 157 | 185 |
| 38 | 31 | 58 | 81 | 100 | 155 | 182 |
| 37 | 32 | 59 | 81 | 100 | 152 | 177 |
| 36 | 33 | 60 | 82 | 100 | 149 | 172 |
| 35 | 34 | 61 | 82 | 100 | 146 | 167 |
| 34 | 35 | 62 | 83 | 100 | 143 | 162 |
| 33 | 36 | 63 | 84 | 100 | 139 | 157 ← 1981 |
| 32 | 37 | 64 | 84 | 100 | 135 | 152 |
| 31 | 39 | 66 | 85 | 100 | 132 | 146 |

# 4. LOCAL-STORM PMP FOR THE SOUTHWESTERN REGION AND CALIFORNIA

## 4.1 Introduction

This chapter provides generalized estimates of local or thunderstorm probable maximum precipitation. By "generalized" is meant that mapped values are given from which estimates of PMP may be determined for any selected drainage.

### 4.1.1 Region of Interest

Local-storm PMP was not included in the "Interim Report, Probable Maximum Precipitation in California" (HMR No. 36). During the formulation of the present study, we decided that the local-storm part of the study should include California west of the Sierra Nevada. It was also noted that PMP for summer thunderstorms was not considered west of the Cascade Divide in the Northwestern Region (HMR No. 43). As stated in the latter report, "No summer thunderstorms have been reported there (west of the Divide) of an intensity of those to the east, for which the moisture source is often the Gulf of Mexico or Gulf of California. The Cascade Divide offers an additional barrier to such moisture inflows to coastal areas where, in addition, the Pacific Ocean to the west has a stabilizing influence on the air to hinder the occurrence of intense summer local storms." Therefore, it was necessary to establish some continuation of the Cascade Divide into California so that the local-storm PMP definition would have continuity between the two regions.

The stabilizing influence of the Pacific air is at times interrupted by the warm moist tropical air from the south pushing into California, although it is difficult to determine where the limit of southerly flow occurs. General storms having the tropical characteristic of excessive thunderstorm rains are observed as far north as the northern end of the Sacramento Valley. Thus, a northern boundary has been selected for this study, excluding that portion of

**Table C.3 Local PMP**

| Steps: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| 1. Average 1-hr 1-mi^2 (2.6 km^2) PMP for drainage (in) (Fig. 4.5) | 11.6 | | | | | | | | |
| 2. a. Reduction for elevation. [ No adjustment for elevations | | | | | | | | | |
| up to 5,000 feet (1,524 m): 5% decrease per | | | | | | | | | |
| 1,000 feet (305 m) above 5,000 feet (1,524 m) ] | 100% | | | | | | | | |
| b. Multiply step 1 by step 2a | 11.6 | | | | | | | | |
| 3. Average 6/1-hr ratio for drainage (Fig. 4.7) | 1.25 | | | | | | | | |
| | **Duration (hr)** | | | | | | | | |
| | **1/4** | **1/2** | **3/4** | **1** | **2** | **3** | **4** | **5** | **6** |
| 4. Durational variation for 6/1-hr ratio of step 3 (Table 4.4) | 74% | 89% | 95% | 100% | 112% | 118% | 121% | 123% | 125% |
| 5. 1-mi^2 (2.6 km^2) PMP for indicated durations | | | | | | | | | |
| (step 2b x step 4) | 8.6 | 10.3 | 11.0 | 11.6 | 13.0 | 13.7 | 14.0 | 14.3 | 14.5 |
| 6. Areal reduction (Fig. 4.9) | 70% | 76% | 79% | 81% | 83% | 84% | 86% | 87% | 88% |
| 7. Areal reduced PMP (steps 5 x 6) | 6.0 | 7.8 | 8.7 | 9.4 | 10.8 | 11.5 | 12.0 | 12.4 | 12.8 |
| 8. Incremental PMP (successive subtraction in step 7) | | | | 9.4 | 1.4 | 0.7 | 0.5 | 0.4 | 0.4 |
| | 6.0 | 1.8 | 0.9 | 0.7 | | | | | |
| | | | | | | | | | |
| 9. Time sequence of incremental PMP according to | | | | least | 4th | 2nd | largest | 3rd | 5th |
| Hourly incerements (table 4.7) | | | | 0.4 | 0.5 | 1.4 | 9.4 | 0.7 | 0.4 |
| Four largest 15-min incerements (table 4.8) | 6.0 | 1.8 | 0.9 | 0.7 | | | | | |

Notes:
1. Latitude: 33 27, Longitude: 111 38 of basin center
2. Area: 13.0 mi^2
3. Precipitation depths are computed by using the procedures and guidelines in HMR 49 (1977)
4. See Table C.5 for Local PMP distribution

Local Storm PMP



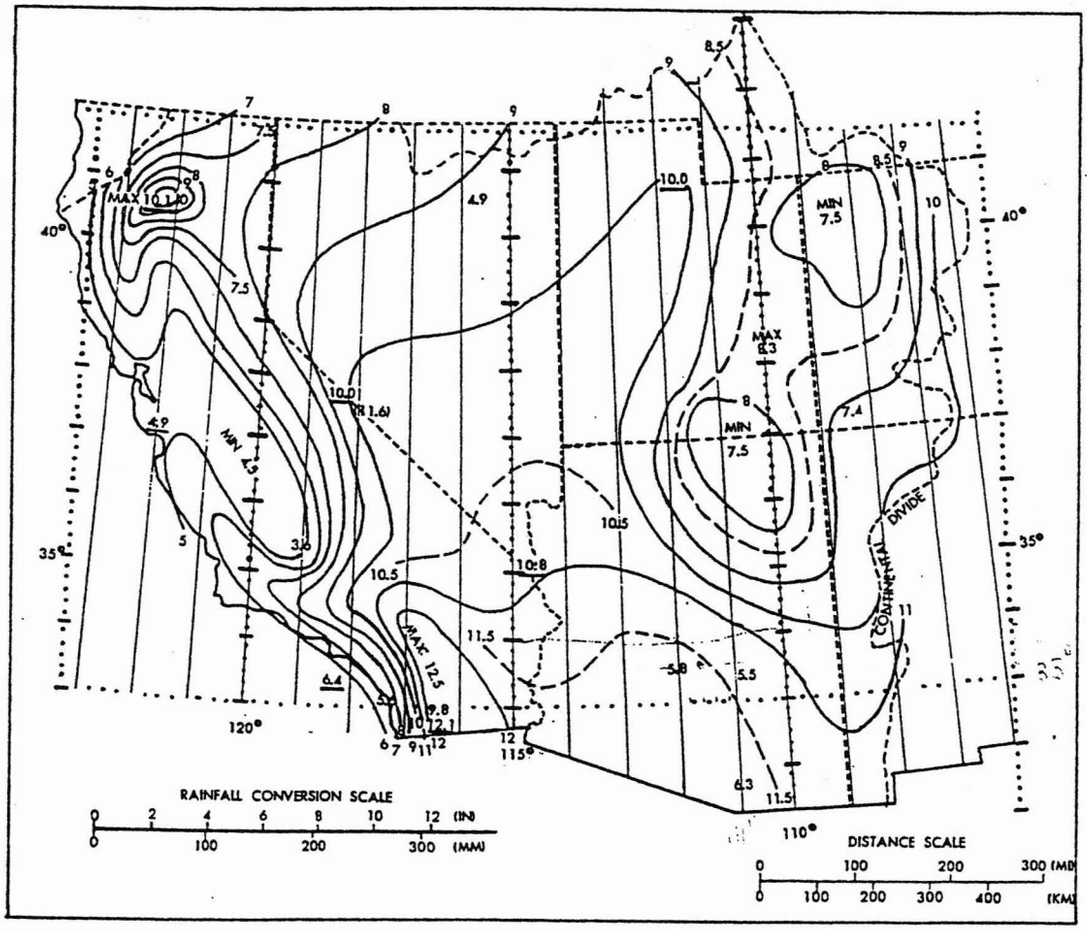



*Figure 4.5--Local-storm PMP for 1 mi$^2$ (2.6 km$^2$) 1 hr. Directly applicable for locations between sea level and 5000 ft (1524 m). Elevation adjustment must be applied for locations above 5000 ft.*

events. In contrast to figure 4.4, figure 4.5 maintains a maximum between these two locations. There is no known meteorological basis for a different solution. The analysis suggests that in the northern portion of the region maximum PMP occurs between the Sierra Nevada on the west and the Wasatch range on the east.

A discrete maximum (> 10 inches, 254 mm) occurs at the north end of the Sacramento Valley in northern California because the northward-flowing moist air is increasingly channeled and forced upslope. Support for this PMP center comes from the Newton, Kennett, and Red Bluff storms (fig. 4.1). Although the analysis in this region appears to be an extension of the broad maximum through the center of the Southwestern Region, it does not indicate the direction of moist inflow. The pattern has evolved primarily as a result of attempts to tie plotted maxima into a reasonable picture while considering inflow directions, terrain effects, and moisture potential.

Local storm PMP = 11.6"

11.6" (1981)

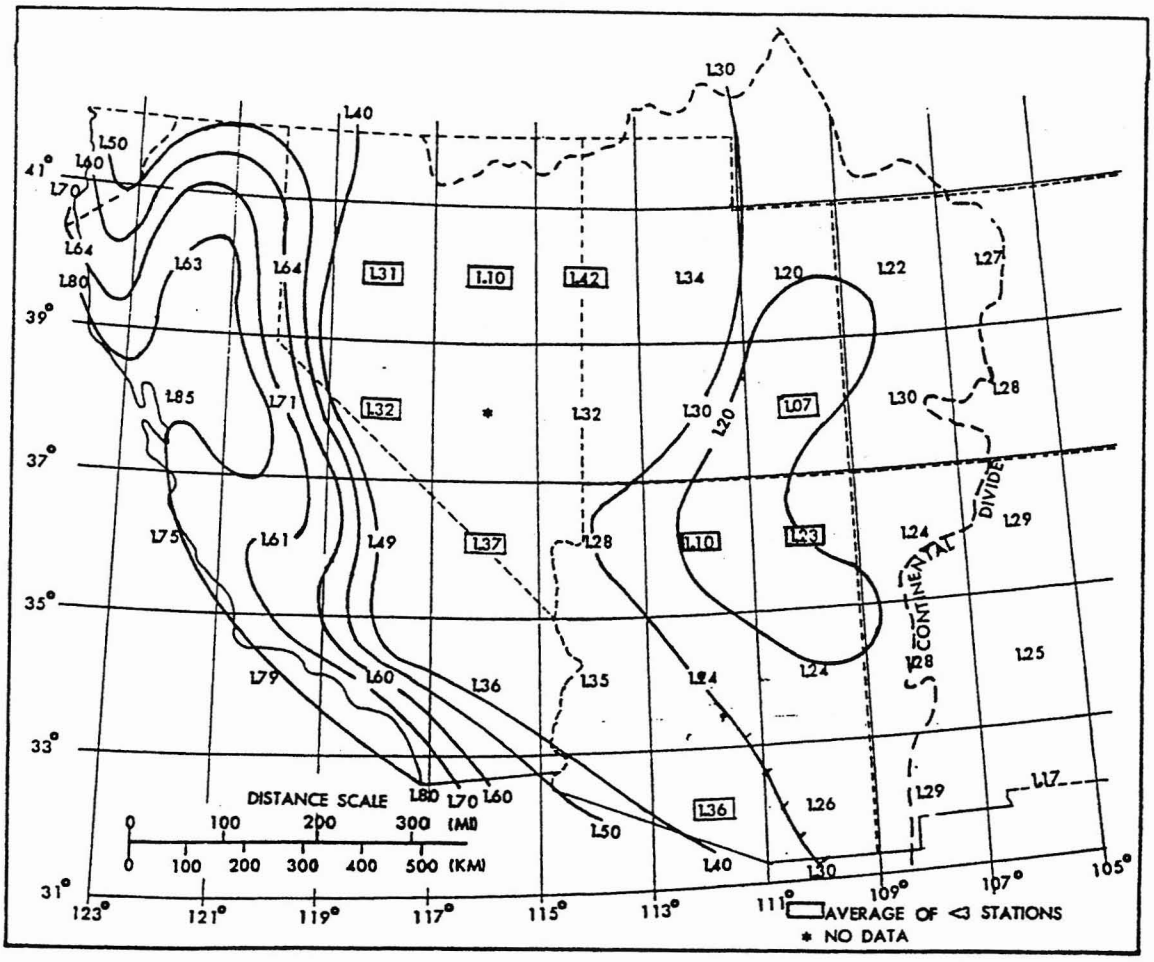



*Figure 4.7.--Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).*

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945- ). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

Average 6/1-hr ratio for drainage: 1.25

1.25 (1981)

ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi$^2$ (2.6-km$^2$) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

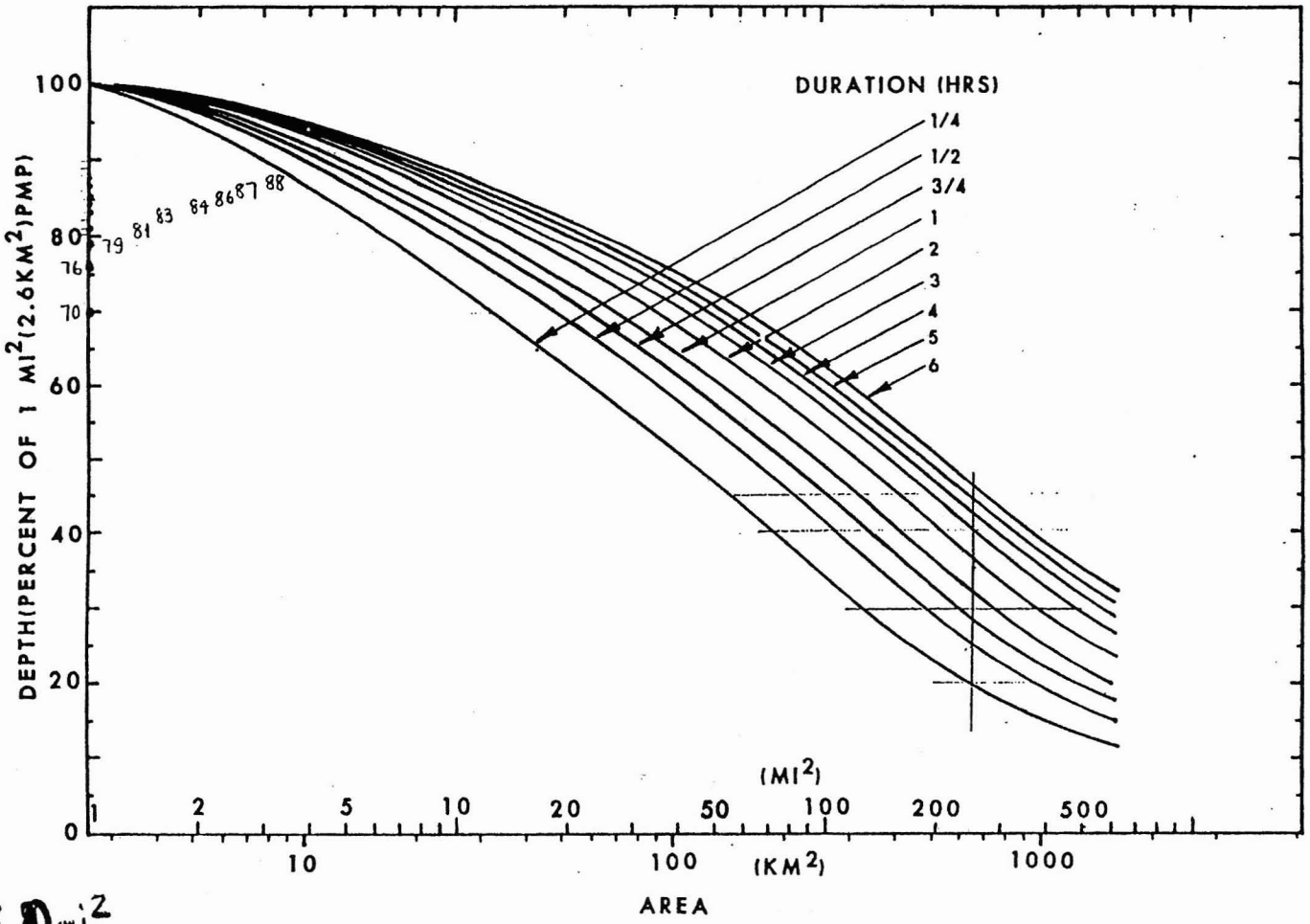
To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi$^2$ (2.6-km$^2$) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

| 6/1-hr ratio | Duration (hr) 1/4 | 1/2 | 3/4 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|
| 1.1 | 86 | 93 | 97 | 100 | 107 | 109 | 110 | 110 | 110 |
| 1.2 | 74 | 89 | 95 | 100 | 110 | 115 | 118 | 119 | 120 |
| 1.3 | 74 | 89 | 95 | 100 | 114 | 121 | 125 | 128 | 130 |
| 1.4 | 63 | 83 | 93 | 100 | 118 | 126 | 132 | 137 | 140 |
| 1.5 | 63 | 83 | 93 | 100 | 121 | 132 | 140 | 145 | 150 |
| 1.6 | 43 | 70 | 87 | 100 | 124 | 138 | 147 | 154 | 160 |
| 1.8 | 43 | 70 | 87 | 100 | 130 | 149 | 161 | 171 | 180 |
| 2.0 | 43 | 70 | 87 | 100 | 137 | 161 | 175 | 188 | 200 |

## 4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi$^2$ (2.6 km$^2$). To apply PMP to a basin, we need to determine how 1-mi$^2$ (2.6-km$^2$) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

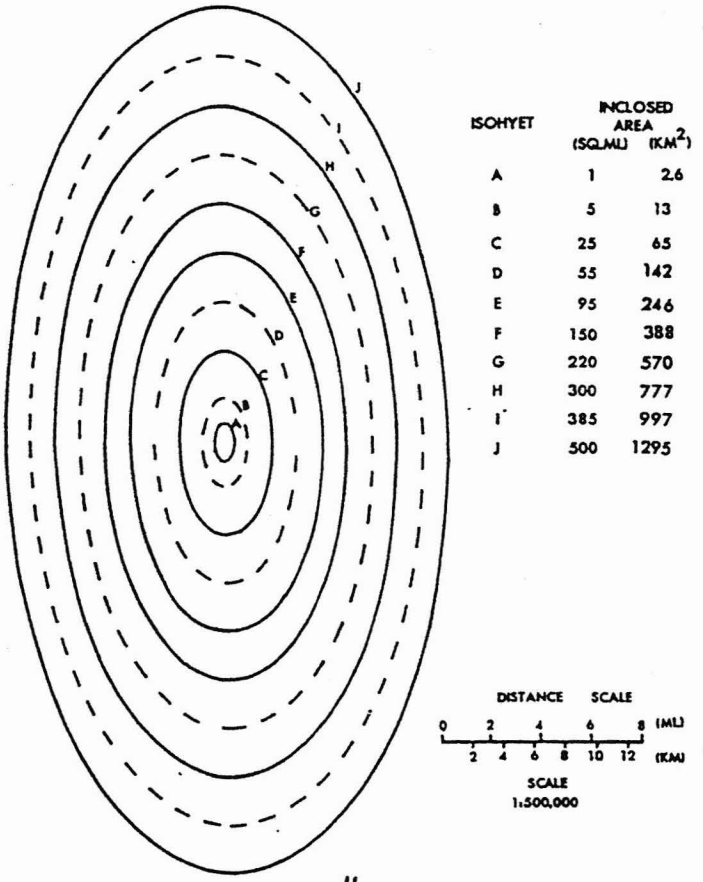



Area = 13.0 mi²

Area = 11.3 mi² (1981)

*Figure 4.9.--Adopted depth-area relations for local-storm PMP.*

| Duration (hr) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Areal Reduction | 1/4 | 1/2 | 3/4 | 1 | 2 | 3 | 4 | 5 | 6 |
| | 70 | 76 | 79 | 81 | 83 | 84 | 86 | 87 | 88 ✓ (DMJM) |
| | 72 | 78 | 80 | 82 | 84 | 85 | 86 | 87 | 88 (1981) |




| ISOHYET | INCLOSED AREA (SQ.MI.) | (KM$^2$) |
|---|---|---|
| A | 1 | 2.6 |
| B | 5 | 13 |
| C | 25 | 65 |
| D | 55 | 142 |
| E | 95 | 246 |
| F | 150 | 388 |
| G | 220 | 570 |
| H | 300 | 777 |
| I | 385 | 997 |
| J | 500 | 1295 |

*Figure 4.10.--Idealized local-storm isohyetal pattern.*

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, the choice of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

| Increment | HMR No. 5[1] Sequence Position | EM1110-2-1411[2] Sequence Position |
|---|---|---|
| Largest hourly amount | Third | Fourth |
| 2nd largest | Fourth | Third |
| 3rd largest | Second | Fifth |
| 4th largest | Fifth | Second |
| 5th largest | First | Last |
| least | Last | First |

[1] U. S. Weather Bureau 1947.
[2] U. S. Corps of Engineers 1952.

Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.—Time sequence for 15-min incremental PMP within 1 hr.

| Increment | Sequence Position |
|---|---|
| Largest 15-min amount | First |
| 2nd largest | Second |
| 3rd largest | Third |
| least | Last |

## 4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| | M | J | J | A | S | O | No. of Cases |
| Utah | 1 | 5 | 9 | 14 | 5 | | 34 |
| Arizona | | 4 | 16 | 19 | 4 | | 43 |
| S. Calif.* | | 14 | 10 | 7 | | | 31 |
| No. of cases/mo. | 1 | 23 | 35 | 40 | 9 | 0 | |

*South of 37°N and east of Sierra Nevada ridgeline.

**Table C.4 General PMP Distribution**

| Time (hr) | PMP Distribution | Incremental PMP (in) | Accumulated PMP (in) | Accumulated PMP Distribution |
|---|---|---|---|---|
| 0 | | 0.000 | 0.000 | 0.000 |
| 6 | 0.725 | 0.037 | 0.725 | 0.037 |
| 12 | 0.725 | 0.037 | 1.450 | 0.075 |
| 18 | 0.725 | 0.037 | 2.175 | 0.112 |
| 24 | 0.725 | 0.037 | 2.900 | 0.149 |
| 30 | 1.502 | 0.077 | 4.402 | 0.227 |
| 36 | 2.638 | 0.136 | 7.040 | 0.363 |
| 42 | 10.203 | 0.526 | 17.243 | 0.888 |
| 48 | 1.068 | 0.055 | 18.311 | 0.943 |
| 54 | 0.275 | 0.014 | 18.586 | 0.957 |
| 60 | 0.275 | 0.014 | 18.861 | 0.972 |
| 66 | 0.275 | 0.014 | 19.136 | 0.986 |
| 72 | 0.275 | 0.014 | 19.411 | 1.000 |

Note:
General PMP was distributed by using the guidance provided by Mr. Michael Greenslade and Mr. John Linkswiler of ADWR on November 15, 2000.
The e-mail correspondance is provided on the following page.

## Tuncok, Kaan

**From:** Mike Greenslade [mdgreenslade@ADWR.STATE.AZ.US]
**Sent:** Wednesday, November 15, 2000 8:45 AM
**To:** Tuncok, Kaan
**Cc:** John Linkswiler
**Subject:** Spook Hill Dam (07.50)

In response to your telephone call to John Linkswiler regarding Spook Hill Dam. John indicated that you were interested in information contained in our files. We have an extensive file on this dam including as-built drawings and the original design report. You are welcome to come to our office and request to review this information. If you need copies of reports we will require that you arrange for a copy service to make the copies. We are requiring this because of problems in the past with originals not being returned in a timely manner or damaged.

Also, John indicated to me that as part of his review of the PMP determination, he would accept an HMR 49 general storm (3-day storm) distribution as follows:

1st Day - Use the 2nd largest day of the 3-day storm with equal 6-hr increments.

2nd Day - Use the largest day of the 3-day storm broken into unequal 6-hr increments as follows: (3rd largest 6-hr, 2nd largest 6-hr, 1st largest 6-hr & 4th largest 6-hr)

3rd Day - Use the 3nd largest day of the 3-day storm with equal 6-hr increments.

Michael Greenslade, P.E.
ADWR, Dam Safety Section
500 North Third Street
Phoenix, Arizona 85004-3903

Phone: (602) 417-2400 x7188
Fax: (602) 417-2423
E-mail: mdgreenslade@adwr.state.az.us

**Table C.5 Local PMP Distribution**

| Time (hr) | PMP Distribution | Incremental PMP (in) | Accumulated PMP (in) | Accumulated PMP Distribution |
|---|---|---|---|---|
| | | 0.000 | 0.000 | 0.000 |
| 0.3 | 0.100 | 0.008 | 0.100 | 0.008 |
| 0.5 | 0.100 | 0.008 | 0.200 | 0.016 |
| 0.8 | 0.100 | 0.008 | 0.300 | 0.023 |
| 1.0 | 0.100 | 0.008 | 0.400 | 0.031 |
| 1.3 | 0.125 | 0.010 | 0.525 | 0.041 |
| 1.5 | 0.125 | 0.010 | 0.650 | 0.051 |
| 1.8 | 0.125 | 0.010 | 0.775 | 0.061 |
| 2.0 | 0.125 | 0.010 | 0.900 | 0.070 |
| 2.3 | 0.350 | 0.027 | 1.250 | 0.098 |
| 2.5 | 0.350 | 0.027 | 1.600 | 0.125 |
| 2.8 | 0.350 | 0.027 | 1.950 | 0.152 |
| 3.0 | 0.350 | 0.027 | 2.300 | 0.180 |
| 3.3 | 6.000 | 0.469 | 8.300 | 0.648 |
| 3.5 | 1.800 | 0.141 | 10.100 | 0.789 |
| 3.8 | 0.900 | 0.070 | 11.000 | 0.859 |
| 4.0 | 0.700 | 0.055 | 11.700 | 0.914 |
| 4.3 | 0.175 | 0.014 | 11.875 | 0.928 |
| 4.5 | 0.175 | 0.014 | 12.050 | 0.941 |
| 4.8 | 0.175 | 0.014 | 12.225 | 0.955 |
| 5.0 | 0.175 | 0.014 | 12.400 | 0.969 |
| 5.3 | 0.100 | 0.008 | 12.500 | 0.977 |
| 5.5 | 0.100 | 0.008 | 12.600 | 0.984 |
| 5.8 | 0.100 | 0.008 | 12.700 | 0.992 |
| 6.0 | 0.100 | 0.008 | 12.800 | 1.000 |

Note:
Local PMP was distributed by using the procedures and guidelines in EM1110-2-1411 (USCOE, 1952).

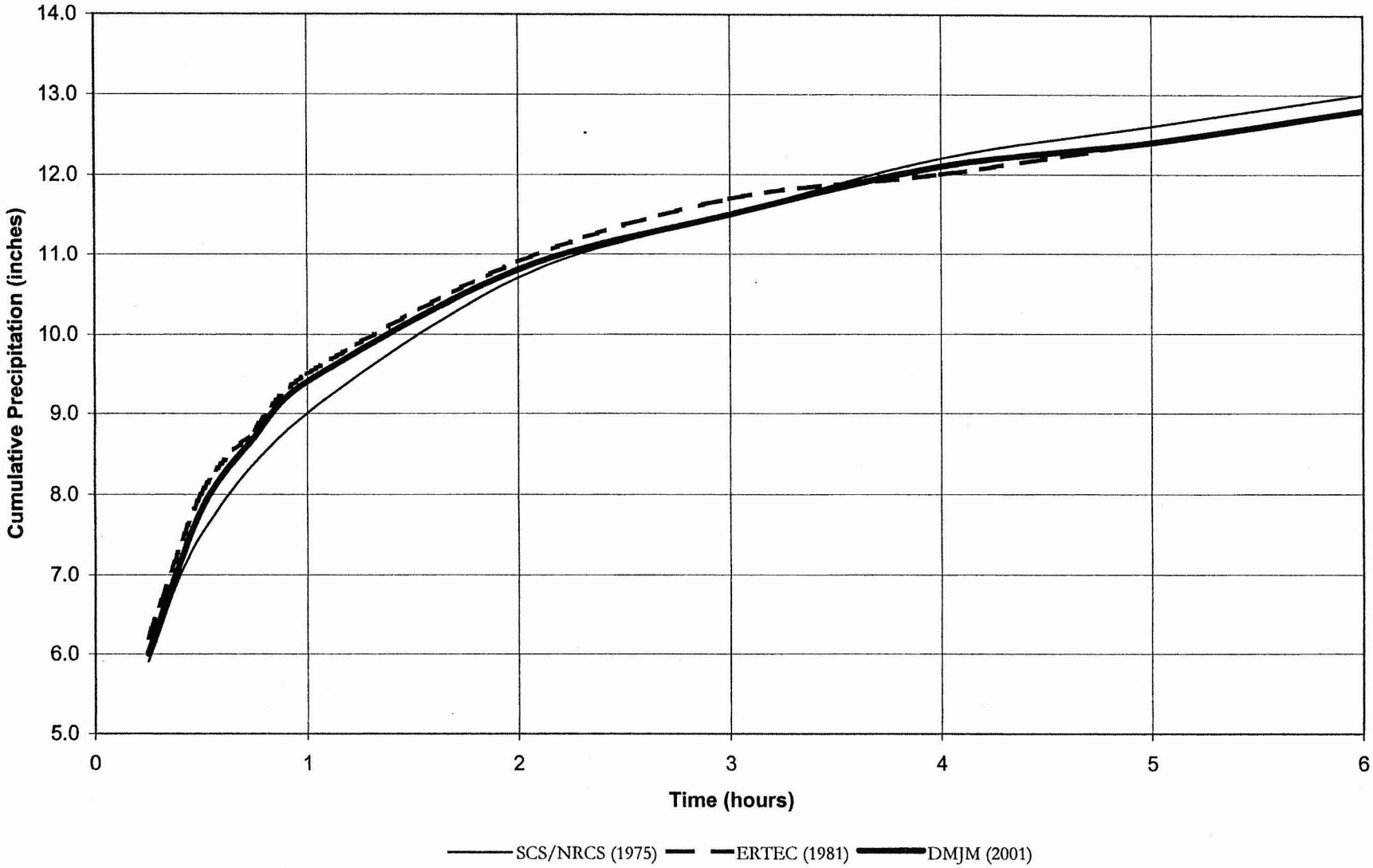
## PRECIPITATION COMPARISON

SPOOK HILL FLOODWATER RETARDING STRUCTURE

| VARIABLE | SCS/NRCS | ERTEC WESTERN, INC. | DMJM |
|---|---|---|---|
| Study Date | 22-Dec-76 | 01-Aug-81 | 01-Dec-00 |
| Drainage Area (sq. miles) | 13.57 | 11.30 | 13.00 |
| | | | |
| Local Storm: | | | |
| PMP (1hr-1sq. Mile) | 11.50 | 11.60 | 11.60 |
| 6hr/1hr Ratio | 1.30 | 1.25 | 1.25 |
| Design Precipitation (inches) | 13.0 | 12.8 | 12.8 |
| | | | |
| General Storm: | | | |
| Total PMP (24-hr, inches) | NA | 14.2 | 15.4 |

## Areal Reduced Probable Maximum Precipitation

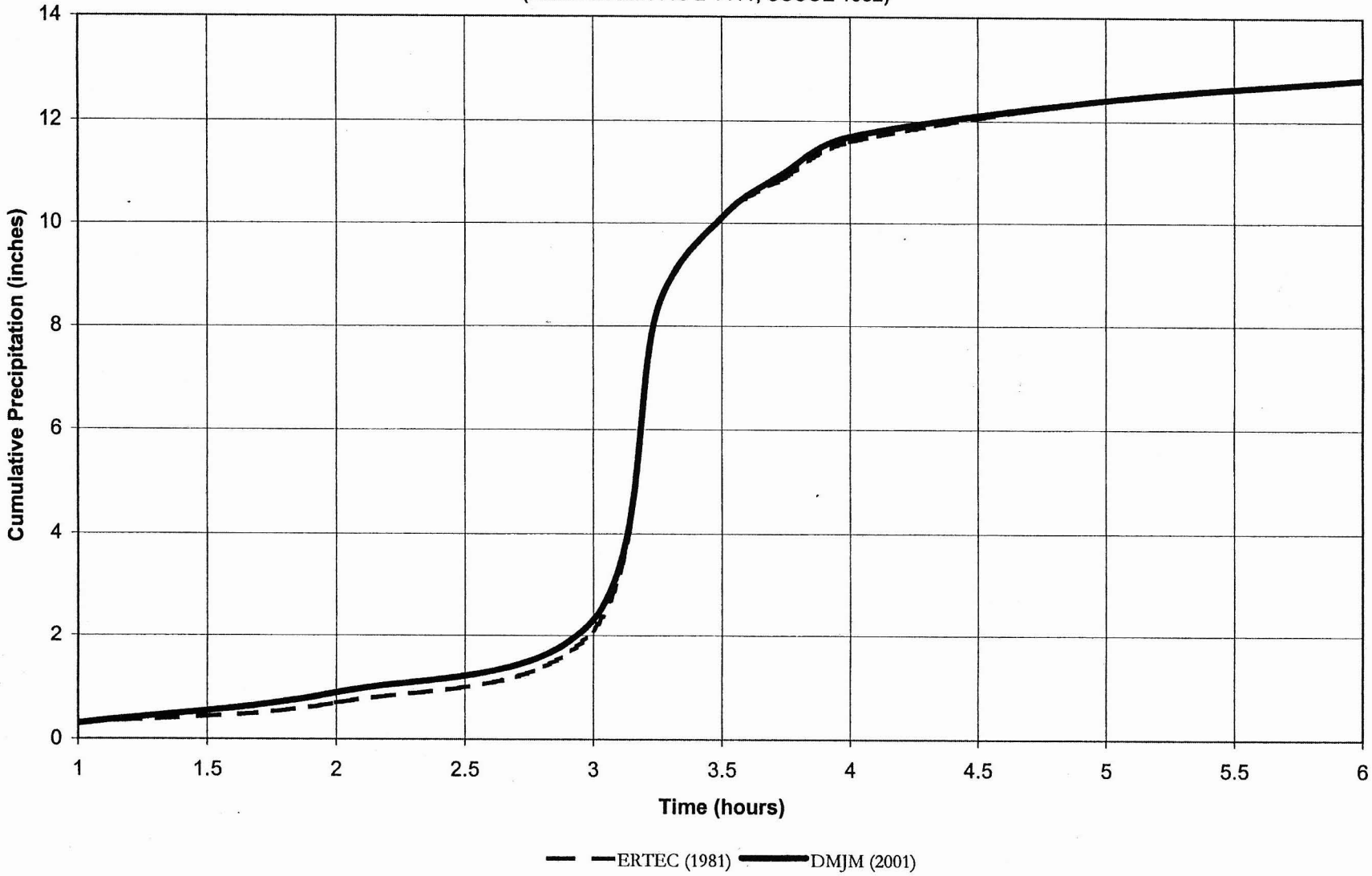
Spook Hill Floodwater Retarding Structure, Mesa, Arizona



## Time Sequence of Incremental Probable Maximum Precipitation

Spook Hill Floodwater Retarding Structure, Mesa, Arizona

(Based on EM1110-2-1411, USCOE 1952)

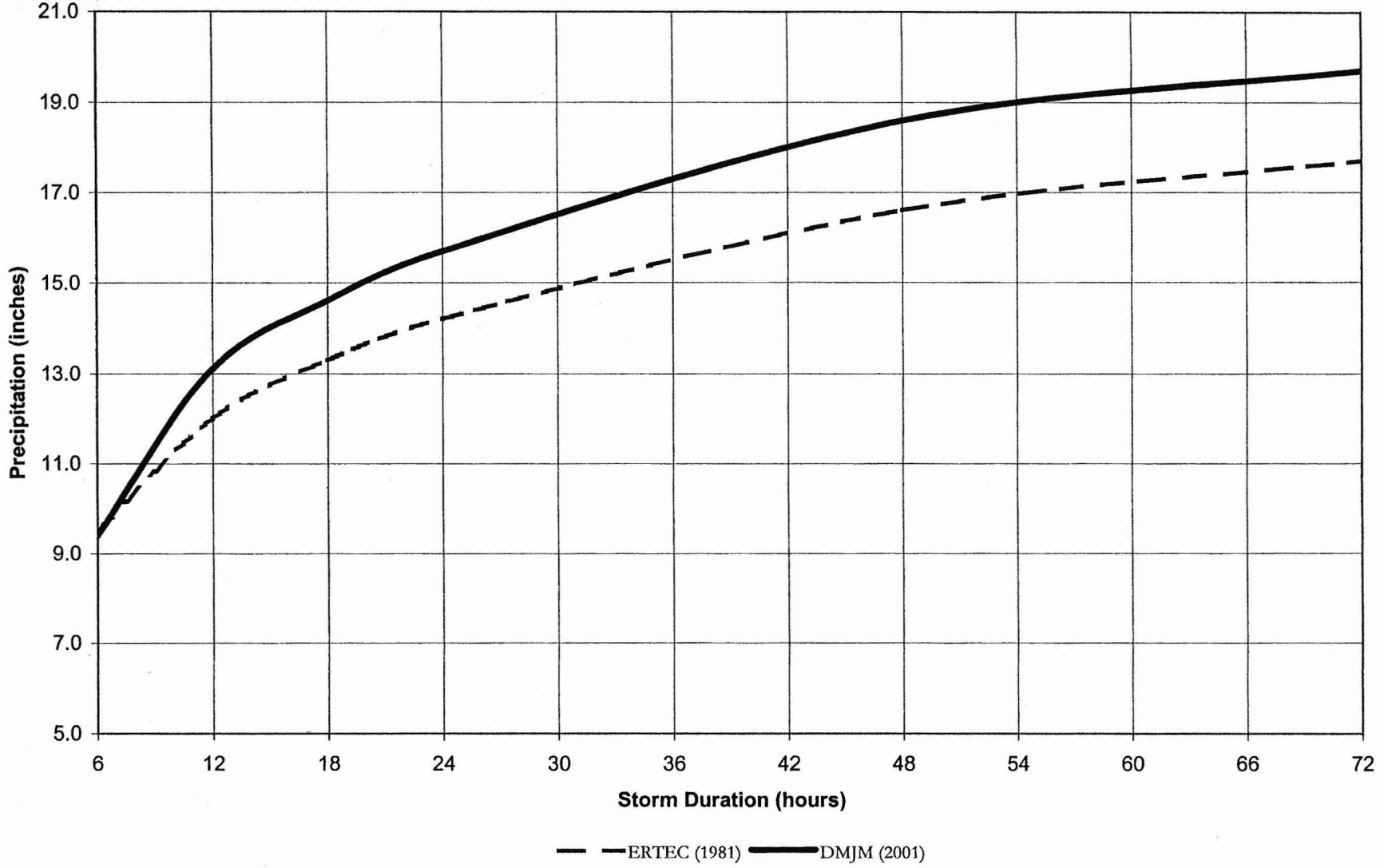



j:\rm06\design\drn\hydrology\report\final report\Precipitation QA-QC.xls(Time Sequence)

DMJM+HARRIS

## General Storm Probable Maximum Precipitation

Spook Hill Floodwater Retarding Structure, Mesa, Arizona



# Appendix C2
# Green-Ampt Infiltration Parameters

**Table C.6 Soil Distribution**

| Subbasin No. | Soil | | | |
|---|---|---|---|---|
| | Area | | Map Unit | Texture |
| | (sq. mi.) | (acres) | (Aguila/Carefree) | |
| **A1** | 0.012 | 8 | 3 | sandy loam |
| | 0.011 | 7 | 44 | very gravelly clay |
| | 0.040 | 26 | 61 | extremely gravelly sandy clay |
| | 0.112 | 71 | 63 | extremely gravelly sandy clay |
| | 0.180 | 115 | 68 | very gravelly sandy loam |
| | 0.392 | 251 | 98 | very gravelly loam |
| | 0.191 | 122 | 115 | sandy loam |
| | 0.026 | 17 | 118 | gravelly sandy loam |
| Total | 0.963 | 616 | | |
| | | | | |
| **B1** | 0.005 | 3 | 3 | sandy loam |
| | 0.417 | 267 | 61 | extremely gravelly sandy clay |
| | 0.550 | 352 | 63 | extremely gravelly sandy clay |
| | 0.301 | 192 | 68 | very gravelly loam |
| | 0.552 | 353 | 90 | gravelly sandy loam |
| | 1.121 | 718 | 98 | very gravelly loam |
| | 0.156 | 100 | 101 | loam |
| | 0.029 | 19 | 110 | gravelly clay loam |
| | 0.133 | 85 | 113 | gravelly sandy loam |
| | 0.172 | 110 | 115 | sandy loam |
| | 0.653 | 418 | 118 | gravelly sandy loam |
| Total | 4.089 | 2617 | | |
| | | | | |
| **B2** | 0.058 | 37 | 61 | extremely gravelly sandy clay |
| | 0.072 | 46 | 63 | extremely gravelly sandy clay |
| | 0.091 | 58 | 90 | gravelly sandy loam |
| | 0.328 | 210 | 98 | very gravelly loam |
| | 0.185 | 118 | 101 | loam |
| | 0.036 | 23 | 110 | gravelly clay loam |
| | 0.126 | 81 | 112 | gravelly sandy loam |
| | 0.215 | 138 | 113 | gravelly sandy loam |
| | 0.185 | 118 | 115 | sandy loam |
| | 0.063 | 40 | 118 | gravelly sandy loam |
| Total | 1.359 | 870 | | |
| | | | | |
| **C1** | 0.195 | 125 | 61 | extremely gravelly sandy clay |
| | 0.213 | 136 | 63 | extremely gravelly sandy clay |
| | 0.405 | 259 | 68 | very gravelly sandy loam |
| | 0.488 | 312 | 90 | gravelly sandy loam |
| | 0.790 | 506 | 98 | very gravelly loam |
| | 0.014 | 9 | 101 | |
| | 0.174 | 111 | 110 | gravelly clay loam |
| | 0.036 | 23 | 112 | gravelly sandy loam |
| | 0.037 | 24 | 113 | |
| | 0.032 | 20 | 115 | sandy loam |
| | 0.154 | 98 | 118 | gravelly sandy loam |
| Total | 2.537 | 1624 | | |

**Table C.6 (continued)**

| Subbasin No. | Soil | | | |
|---|---|---|---|---|
| | Area | | Map Unit | Texture |
| | (sq. mi.) | (acres) | (Aguila/Carefree) | |
| **D1** | 0.015 | 9 | 44 | very gravelly clay |
| | 0.051 | 33 | 63 | extremely gravelly sandy clay |
| | 0.735 | 471 | 68 | very gravelly sandy loam |
| | 0.075 | 48 | 90 | gravelly sandy loam |
| | 0.016 | 10 | 98 | very gravelly loam |
| | 0.254 | 163 | 115 | sandy loam |
| Total | 1.146 | 733 | | |
| | | | | |
| **F** | 0.019 | 12 | 44 | very gravelly clay |
| | 0.108 | 69 | 98 | very gravelly loam |
| | 0.027 | 17 | 3 | sandy loam |
| Total | 0.154 | 99 | | |
| | | | | |
| **G** | 0.164 | 105 | 44 | very gravelly clay |
| | 0.355 | 227 | 98 | very gravelly loam |
| Total | 0.519 | 332 | | |
| | | | | |
| **H** | 0.024 | 15 | 61 | extremely gravelly sandy clay |
| | 0.152 | 97 | 63 | extremely gravelly sandy clay |
| | 0.003 | 2 | 44 | very gravelly clay |
| | 0.569 | 364 | 98 | very gravelly loam |
| | 0.060 | 38 | 68 | very gravelly sandy loam |
| | 0.005 | 3 | 115 | sandy loam |
| | 0.045 | 28 | 118 | gravelly sandy loam |
| Total | 0.858 | 549 | | |
| | | | | |
| **I** | 0.108 | 69 | 61 | extremely gravelly sandy clay |
| | 0.138 | 88 | 63 | extremely gravelly sandy clay |
| | 0.056 | 36 | 44 | very gravelly clay |
| | 0.504 | 323 | 98 | very gravelly loam |
| | 0.110 | 70 | 68 | very gravelly sandy loam |
| | 0.162 | 104 | 115 | sandy loam |
| | 0.237 | 152 | 118 | gravelly sandy loam |
| Total | 1.315 | 842 | | |

Note: DDMSW Soil Data is presented on the following page

## Soil Data



| Area Id | Soil Survey | Map Unit | Area | Area Pct (%) | XKSAT | Rock Outcrop (%) | Effective (%) |
|---|---|---|---|---|---|---|---|
| F | Aguila/Carefree | 44 | 0.019 | 12.3 | 0.03 | | |
| | Aguila/Carefree | 98 | 0.108 | 70.1 | 0.37 | | |
| | Aguila/Carefree | 3 | 0.027 | 17.5 | 0.58 | | |
| G | Aguila/Carefree | 44 | 0.164 | 31.6 | 0.03 | | |
| | Aguila/Carefree | 98 | 0.355 | 68.4 | 0.37 | | |
| H | Aguila/Carefree | 61 | 0.024 | 2.8 | 0.15 | | |
| | Aguila/Carefree | 63 | 0.152 | 17.7 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 44 | 0.003 | 0.3 | 0.03 | | |
| | Aguila/Carefree | 98 | 0.569 | 66.3 | 0.37 | | |
| | Aguila/Carefree | 68 | 0.060 | 7.0 | 0.63 | | |
| | Aguila/Carefree | 115 | 0.005 | 0.6 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.045 | 5.2 | 0.42 | | |
| I | Aguila/Carefree | 115 | 0.162 | 12.3 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.237 | 18.0 | 0.42 | | |
| | Aguila/Carefree | 63 | 0.138 | 10.5 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 44 | 0.056 | 4.3 | 0.03 | | |
| | Aguila/Carefree | 98 | 0.504 | 38.3 | 0.37 | | |
| | Aguila/Carefree | 68 | 0.110 | 8.4 | 0.63 | | |
| | Aguila/Carefree | 61 | 0.108 | 8.2 | 0.15 | | |
| A1 | Aguila/Carefree | 3 | 0.012 | 1.2 | 0.58 | | |
| | Aguila/Carefree | 44 | 0.011 | 1.1 | 0.03 | | |
| | Aguila/Carefree | 61 | 0.040 | 4.1 | 0.15 | | |
| | Aguila/Carefree | 63 | 0.112 | 11.6 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 68 | 0.180 | 18.7 | 0.63 | | |
| | Aguila/Carefree | 98 | 0.392 | 40.7 | 0.37 | | |
| | Aguila/Carefree | 115 | 0.191 | 19.8 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.026 | 2.7 | 0.42 | | |
| B1 | Aguila/Carefree | 3 | 0.005 | 0.1 | 0.58 | | |
| | Aguila/Carefree | 61 | 0.417 | 10.2 | 0.15 | | |
| | Aguila/Carefree | 63 | 0.550 | 13.5 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 68 | 0.301 | 7.4 | 0.63 | | |
| | Aguila/Carefree | 90 | 0.552 | 13.5 | 0.39 | | |
| | Aguila/Carefree | 98 | 1.121 | 27.4 | 0.37 | | |
| | Aguila/Carefree | 101 | 0.156 | 3.8 | 0.28 | | |
| | Aguila/Carefree | 110 | 0.029 | 0.7 | 0.13 | | |
| | Aguila/Carefree | 113 | 0.133 | 3.3 | 0.39 | | |
| | Aguila/Carefree | 115 | 0.172 | 4.2 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.653 | 16.0 | 0.42 | | |
| B2 | Aguila/Carefree | 61 | 0.058 | 4.3 | 0.15 | | |
| | Aguila/Carefree | 63 | 0.072 | 5.3 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 90 | 0.091 | 6.7 | 0.39 | | |
| | Aguila/Carefree | 98 | 0.328 | 24.1 | 0.37 | | |
| | Aguila/Carefree | 101 | 0.185 | 13.6 | 0.28 | | |
| | Aguila/Carefree | 110 | 0.036 | 2.6 | 0.13 | | |
| | Aguila/Carefree | 112 | 0.126 | 9.3 | 0.39 | | |
| | Aguila/Carefree | 113 | 0.215 | 15.8 | 0.39 | | |
| | Aguila/Carefree | 115 | 0.185 | 13.6 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.063 | 4.6 | 0.42 | | |
| C1 | Aguila/Carefree | 61 | 0.195 | 7.7 | 0.15 | | |



* Custom Value (not default value)

## Soil Data



| Area Id | Soil Survey | Map Unit | Area | Area Pct (%) | XKSAT | Rock Outcrop (%) | Effective (%) |
|---|---|---|---|---|---|---|---|
| **C1** | Aguila/Carefree | 63 | 0.213 | 8.4 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 68 | 0.405 | 16.0 | 0.63 | | |
| | Aguila/Carefree | 90 | 0.488 | 19.2 | 0.39 | | |
| | Aguila/Carefree | 98 | 0.790 | 31.1 | 0.37 | | |
| | Aguila/Carefree | 101 | 0.014 | 0.6 | 0.28 | | |
| | Aguila/Carefree | 110 | 0.174 | 6.9 | 0.13 | | |
| | Aguila/Carefree | 112 | 0.036 | 1.4 | 0.39 | | |
| | Aguila/Carefree | 113 | 0.037 | 1.5 | 0.39 | | |
| | Aguila/Carefree | 115 | 0.032 | 1.3 | 0.39 | | |
| | Aguila/Carefree | 118 | 0.154 | 6.1 | 0.42 | | |
| **D1** | Aguila/Carefree | 44 | 0.015 | 1.3 | 0.03 | | |
| | Aguila/Carefree | 63 | 0.051 | 4.5 | 0.14 | 25.0 | 100 |
| | Aguila/Carefree | 68 | 0.735 | 64.1 | 0.63 | | |
| | Aguila/Carefree | 90 | 0.075 | 6.5 | 0.39 | | |
| | Aguila/Carefree | 98 | 0.016 | 1.4 | 0.37 | | |
| | Aguila/Carefree | 115 | 0.254 | 22.2 | 0.39 | | |



* Custom Value (not default value)

**Table C.7 Land Use Distribution**

| Subbasin No. | Land Use | | |
|---|---|---|---|
| | Area | | Type |
| | (sq. mi.) | (acres) | |
| **A1** | 0.033 | 21 | MOUNTAIN |
| | 0.110 | 70 | DESERT |
| | 0.472 | 302 | LDR |
| | 0.170 | 109 | MDR |
| | 0.177 | 113 | VLDR |
| Total | 0.963 | 616 | |
| | | | |
| **B1** | 0.353 | 226 | FOREST |
| | 0.118 | 76 | DESERT |
| | 1.554 | 995 | LDR |
| | 0.122 | 78 | MOUNTAIN |
| | 1.942 | 1243 | VLDR |
| Total | 4.089 | 2617 | |
| | | | |
| **B2** | 0.116 | 74 | DESERT |
| | 1.194 | 764 | LDR |
| | 0.028 | 18 | MOUNTAIN |
| | 0.021 | 13 | VLDR |
| Total | 1.359 | 870 | |
| | | | |
| **C1** | 0.200 | 128 | DESERT |
| | 1.854 | 1187 | LDR |
| | 0.178 | 114 | MDR |
| | 0.168 | 108 | MOUNTAIN |
| | 0.137 | 88 | VLDR |
| Total | 2.537 | 1624 | |
| | | | |
| **D1** | 0.069 | 44 | DESERT |
| | 0.609 | 390 | LDR |
| | 0.063 | 40 | MOUNTAIN |
| | 0.147 | 94 | VLDR |
| | 0.229 | 147 | MDR |
| | 0.029 | 19 | MFR |
| Total | 1.146 | 733 | |
| | | | |
| **D2** | 0.235 | 150 | MOUNTAIN |
| | 0.024 | 15 | DESERT |
| | 0.167 | 107 | LDR |
| | 0.288 | 184 | MDR |
| | 0.184 | 118 | VLDR |
| Total | 0.897 | 574 | |

**Table C.7 (continued)**

| Subbasin No. | Land Use | | |
|---|---|---|---|
| | Area | | Type |
| | (sq. mi.) | (acres) | |
| F | 0.066 | 42 | LDR |
| | 0.088 | 56 | VLDR |
| Total | 0.154 | 99 | |
| | | | |
| G | 0.504 | 323 | LDR |
| | 0.016 | 10 | VLDR |
| Total | 0.519 | 333 | |
| | | | |
| H | 0.412 | 264 | LDR |
| | 0.382 | 245 | VLDR |
| | 0.064 | 41 | MOUNTAIN |
| Total | 0.445 | 286 | |
| | | | |
| I | 0.396 | 254 | LDR |
| | 0.584 | 375 | VLDR |
| | 0.022 | 14 | DESERT |
| | 0.238 | 152 | MDR |
| | 0.075 | 47 | MOUNTAIN |
| Total | 1.315 | 200 | |

Note: DDMSW Land Use Data is presented on the following page

# Land Use Data



| Area Id | Land Use Code | Area | Area Pct (%) | DTHETA Condition | Vegetation Cover (%) | RTIMP (%) | IA (in) | Kn | Kb Type | Kb |
|---|---|---|---|---|---|---|---|---|---|---|
| **F** | L.D.R. | 0.066 | 42.9 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.058 |
| | V.L.D.R. | 0.088 | 57.1 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.056 |
| **G** | L.D.R. | 0.504 | 96.9 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.046 |
| | V.L.D.R. | 0.016 | 3.1 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.066 |
| **H** | L.D.R. | 0.412 | 48.0 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.047 |
| | V.L.D.R. | 0.382 | 44.5 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.047 |
| | MOUNTAIN | 0.064 | 7.5 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.110 |
| **I** | L.D.R. | 0.396 | 30.1 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.047 |
| | V.L.D.R. | 0.584 | 44.4 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.045 |
| | DESERT | 0.022 | 1.7 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.064 |
| | M.D.R. | 0.238 | 18.1 | Normal | 50.0 | 30 | 0.25 | 0.050 | Low | 0.050 |
| | MOUNTAIN | 0.075 | 5.7 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.108 |
| **A1** | DESERT | 0.110 | 11.4 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.055 |
| | V.L.D.R. | 0.177 | 18.4 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.052 |
| | L.D.R. | 0.472 | 49.1 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.046 |
| | M.D.R. | 0.170 | 17.7 | Normal | 50.0 | 30 | 0.25 | 0.050 | Low | 0.052 |
| | MOUNTAIN | 0.033 | 3.4 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.117 |
| **B1** | DESERT | 0.118 | 2.9 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.054 |
| | V.L.D.R. | 1.942 | 47.5 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.037 |
| | L.D.R. | 1.554 | 38.0 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.039 |
| | FOREST | 0.353 | 8.6 | Normal | 90.0 | | 0.15 | | Hi | 0.091 |
| | MOUNTAIN | 0.122 | 3.0 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.103 |
| **B2** | DESERT | 0.116 | 8.5 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.054 |
| | V.L.D.R. | 0.021 | 1.5 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.064 |
| | MOUNTAIN | 0.028 | 2.1 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.119 |
| | L.D.R. | 1.194 | 87.9 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.040 |
| **C1** | DESERT | 0.200 | 7.9 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.051 |
| | V.L.D.R. | 0.137 | 5.4 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.053 |
| | L.D.R. | 1.854 | 73.1 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.038 |
| | M.D.R. | 0.178 | 7.0 | Normal | 50.0 | 30 | 0.25 | 0.050 | Low | 0.052 |
| | MOUNTAIN | 0.168 | 6.6 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.099 |
| **D1** | DESERT | 0.069 | 6.0 | Dry | 25.0 | | 0.35 | 0.030 | Low | 0.057 |



* Custom Value (not default value)

## Land Use Data



| Area Id | Land Use Code | Area | Area Pct (%) | DTHETA Condition | Vegetation Cover (%) | RTIMP (%) | IA (in) | Kn | Kb Type | Kb |
|---|---|---|---|---|---|---|---|---|---|---|
| **D1** | V.L.D.R. | 0.147 | 12.8 | Normal | 20.0 | 5 | 0.30 | 0.050 | Low | 0.053 |
| | L.D.R. | 0.609 | 53.1 | Normal | 50.0 | 15 | 0.30 | 0.050 | Low | 0.044 |
| | M.D.R. | 0.229 | 20.0 | Normal | 50.0 | 30 | 0.25 | 0.050 | Low | 0.050 |
| | M.F.R. | 0.029 | 2.5 | Normal | 50.0 | 45 | 0.25 | 0.050 | Low | 0.063 |
| | MOUNTAIN | 0.063 | 5.5 | Normal | 85.0 | | 0.50 | 0.100 | Hi | 0.110 |



* Custom Value (not default value)

## Sub Basin Data



Basin: 01 Storms: Single Duration: 6 Hour Loss Method: Green-Ampt

| Area ID | Rainfall Losses IA (in) | DTHETA | PSIF (in) | XKSAT (in/hr) | RTIMP (%) |
|---|---|---|---|---|---|
| F | 0.30 | 0.25 | 4.50 | 0.37 | 9 |
| G | 0.30 | 0.25 | 5.70 | 0.24 | 15 |
| H | 0.32 | 0.25 | 4.40 | 0.41 | 14 |
| I | 0.30 | 0.25 | 4.50 | 0.39 | 15 |
| A1 | 0.30 | 0.26 | 4.25 | 0.47 | 16 |
| B1 | 0.29 | 0.25 | 4.45 | 0.41 | 11 |
| B2 | 0.31 | 0.26 | 4.35 | 0.46 | 15 |
| C1 | 0.31 | 0.26 | 4.35 | 0.46 | 15 |
| D1 | 0.30 | 0.27 | 3.64 | 0.67 | 17 |



* Non default value

| DMJM | PROJECT: Red Mtn. Fwy | JOB NO. 6508 | SHEET 1 of 3 |
|---|---|---|---|
| | | DESIGNED BY A.D. | DATE 12/01/00 |
| SUBJECT: Green & Ampt Parameters - BASIN A1 | | CHECKED BY | DATE |

(I) $K_b$ (Representative watershed resistance coefficient)

WE USED DDMS WHICH USES THE EQUATION IN TABLE 5.1 OF THE DRAINAGE DESIGN MANUAL FOR MARICOPA COUNTY (CHAPTER 5)

| AREA % | BASIN A1 (LAND USE DATA) | |
|---|---|---|
| 11.4 | DESERT : .11 $mi^2$ = 70.50 ACRE | Type B |
| 18.4 | VLDR : .1770 $mi^2$ = 113.30 ACRE | Type B |
| 49.1 | LDR : .472 $mi^2$ = 302.10 ACRE | Type B |
| 17.7 | MDR : .170 $mi^2$ = 108.90 ACRE | Type B |
| 3.4 | MOUNT : .033 $mi^2$ = 21.20 ACRE | Type C |

BASED ON THE DESCRIPTION OF TABLE 5.1

FORMULA: $K_b = m \log A + b$

TYPE B :

$m = -0.01375$

$b = 0.08$

DESERT : $(-0.01375)\log(70.50) + 0.08 = .055$

VLDR : $(-0.01375)\log(113.30) + 0.08 = .052$

LDR : $(-0.01375)\log(302.10) + 0.08 = .046$

MDR : $(-0.01375)\log(108.90) + 0.08 = .052$

TYPE C :

$m: -0.025$

$b: 0.15$

MOUNTAIN : $(-0.025)\log(21.20) + 0.15 = .117$

| LAND USE | $K_b$ | % AREA | SUB-$K_b$ |
|---|---|---|---|
| DESERT | .055 | 11.4 | .00627 |
| VLDR | .052 | 18.4 | .009568 |
| LDR | .046 | 49.1 | .02258 |
| MDR | .052 | 17.7 | .009204 |
| MOUNT | .117 | 3.4 | .003978 |
| TOTAL $K_b$ = | | | $\boxed{.052}$ |

| DMJM | PROJECT: Red Mtn. Fwy | JOB NO. 6508 | SHEET 2 of 3 |
|---|---|---|---|
| | | DESIGNED BY AS | DATE 12/01/00 |
| SUBJECT: Green & Ampt Parameters ~ BASIN A1 | | CHECKED BY | DATE |

(II) XKSAT

NOTE: THE FOLLOWING VALUES FOR XKSAT (in/hr) ARE FROM APPENDIX A OF THE DRAINAGE DESIGN MANUAL OF MARICOPA COUNTY (AGUILA-CAREFREE SOIL SURVEY)

BASIN A1 ~ SOILS

| MAP UNIT | XKSAT | AREA (mi²) (ACRE) | AREA % |
|---|---|---|---|
| 3 | .58 | .012 = 7.68 | 1.2 |
| 44 | .03 | .011 = 7.04 | 1.1 |
| 61 | .15 | .040 = 25.6 | 4.1 |
| 63 | .14 | .112 = 71.68 | 11.6 |
| 68 | .63 | .180 = 115.19 | 18.7 |
| 98 | .37 | .392 = 250.87 | 40.7 |
| 115 | .39 | .191 = 122.23 | 19.8 |
| 118 | .42 | .026 = 16.64 | 2.7 |

-USING EQUATION 4.4 OF THE D.D. MANUAL (MARICOPA COUNTY)

$$\overline{XKSAT} = \text{COMPOSITE XKSAT} = \text{ALOG}\left\{ \Sigma A_i \log(XKSAT_i)/A_T \right\}$$

WHERE: $XKSAT_i$ = hydraulic CONDUCTIVITY OF A MAP UNIT, in/hr (FROM APP. A)

$A_i$ = size OF SUBAREA

$A_T$ = size OF THE WATERSHED OR MODELING SUBBASIN

$$\therefore \overline{XKSAT} = \text{ALOG}\left\{ \begin{array}{l} (0.012)\log(.58) + (.011)\log(.03) + (.041)\log(.15) + \\ (.116)\log(.14) + (.187)\log(.63) + (.407)\log(.37) + \\ (.198)\log(.39) + (.027)\log(.42) \end{array} \right\}$$

$$= .349 \text{ in/hr}$$

USIN FIGURE 4.3 FROM THE D.D. MANUAL

PSIF = 4.25 IN

DTHETA (NORMAL) = .26

GO TO STEP (E) for ADJUSTED $\overline{XKSAT}$ based on vegetation

| DMJM | PROJECT: RED MTN FWY | JOB NO. 6508 | SHEET 3 of 3 |
|---|---|---|---|
| | | DESIGNED BY | DATE 12/01/00 |
| SUBJECT: Green & Ampt Parameters - BASIN A1 | | CHECKED BY | DATE |

(III) RTIMP (%) - PERCENT EFFECTIVE IMPERVIOUS AREA

NOTE: TABLE 4.2a FROM DRAINAGE DESIGN MANUAL OF M.C. WAS UTILIZED

BASIN A1

| LU | RTIMP (TABLE 4.2a) | AREA | % AREA |
|---|---|---|---|
| DESERT | 0 | .110 | 11.4 = 0% |
| VLDR | 5 | .177 | 18.4 = 21.60% |
| LDR | 15 | .472 | 49.1 = 57.63% |
| MDR | 30 | .170 | 17.7 = 20.77% |
| MOUNT | 0 | .033 | 3.4 = 0% |

TOTAL % THAT COUNTS = 85.2%

$\therefore \overline{RTIMP} = (5)(0.2160) + (15)(0.5763) + (30)(.2077) \simeq 16\%$

(IV) IA (in)

NOTE: TABLE 4.2a WAS ALSO UTILIZED FOR THIS PARAMETER

| LU | IA |
|---|---|
| DESERT | .35 |
| VLDR | .30 |
| LDR | .30 |
| MDR | .25 |
| MOUNT | .50 |

$\therefore \overline{IA} = (.35)(.114) + (.30)(.184) + (.30)(.491) + (.25)(.177) + (.50)(.034) = \underline{.30 in}$

(V) USING FIGURE 4.4 AND DDMSW DEFAULT PARAMETERS

| LU | % AREA | % VEG COVER ($V_c$) |
|---|---|---|
| DESERT | 11.4 | 25 |
| VLDR | 18.4 | 20 |
| LDR | 49.1 | 50 |
| MDR | 17.7 | 50 |
| MOUNT | 3.4 | 85 |

FROM FCDMC HYDROLOGY MANUAL (1995) USE FIG 4.4 TO COMPUTE $C_k$;

$C_k = V_c - 10/90 + 1.0$

$\therefore$ 25% → $C_k = (25-10)/90 + 1 = 1.167$

85% → $C_k = (85-10)/90 + 1 = 1.833$

20% → $C_k = (20-10)/90 + 1 = 1.111$

50% → $C_k = (50-10)/90 + 1 = 1.444$

$\overline{XKSAT} = [(.114)(1.167) + (.184)(1.111) + (.491)(1.444) + (.177)(1.444) + (.034)(1.833)] * (.349) \Rightarrow 1.36 * 0.349 = \underline{0.47}$

**Source: FCDMC Hydrology Manual**

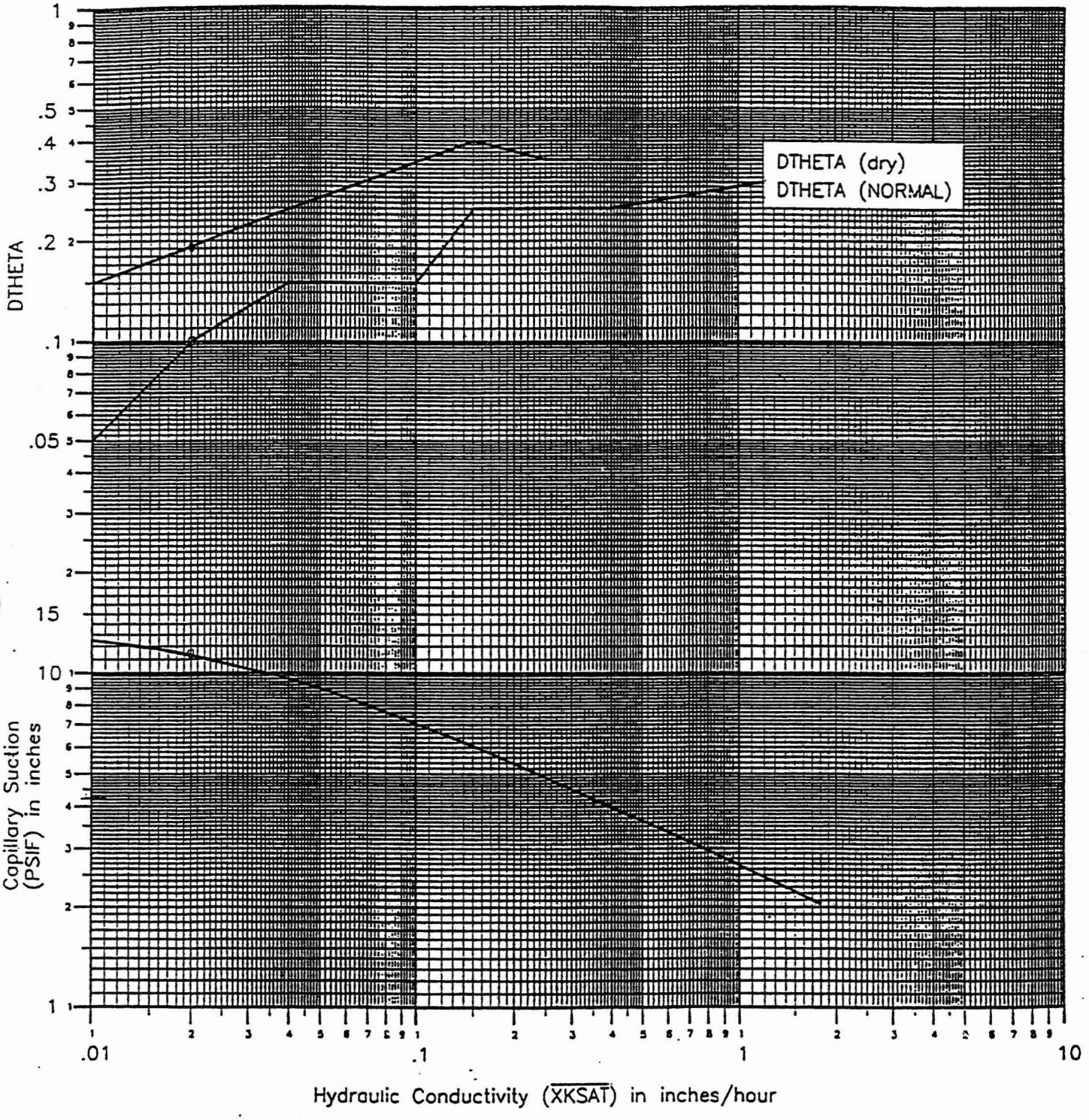



**Figure 4.3**
**Composite Values of PSIF and DTHETA as a function of XKSAT**
**(To be used for area-weighted averaging of Green and Ampt parameters.)**

Source: FCDMC Hydrology Manual

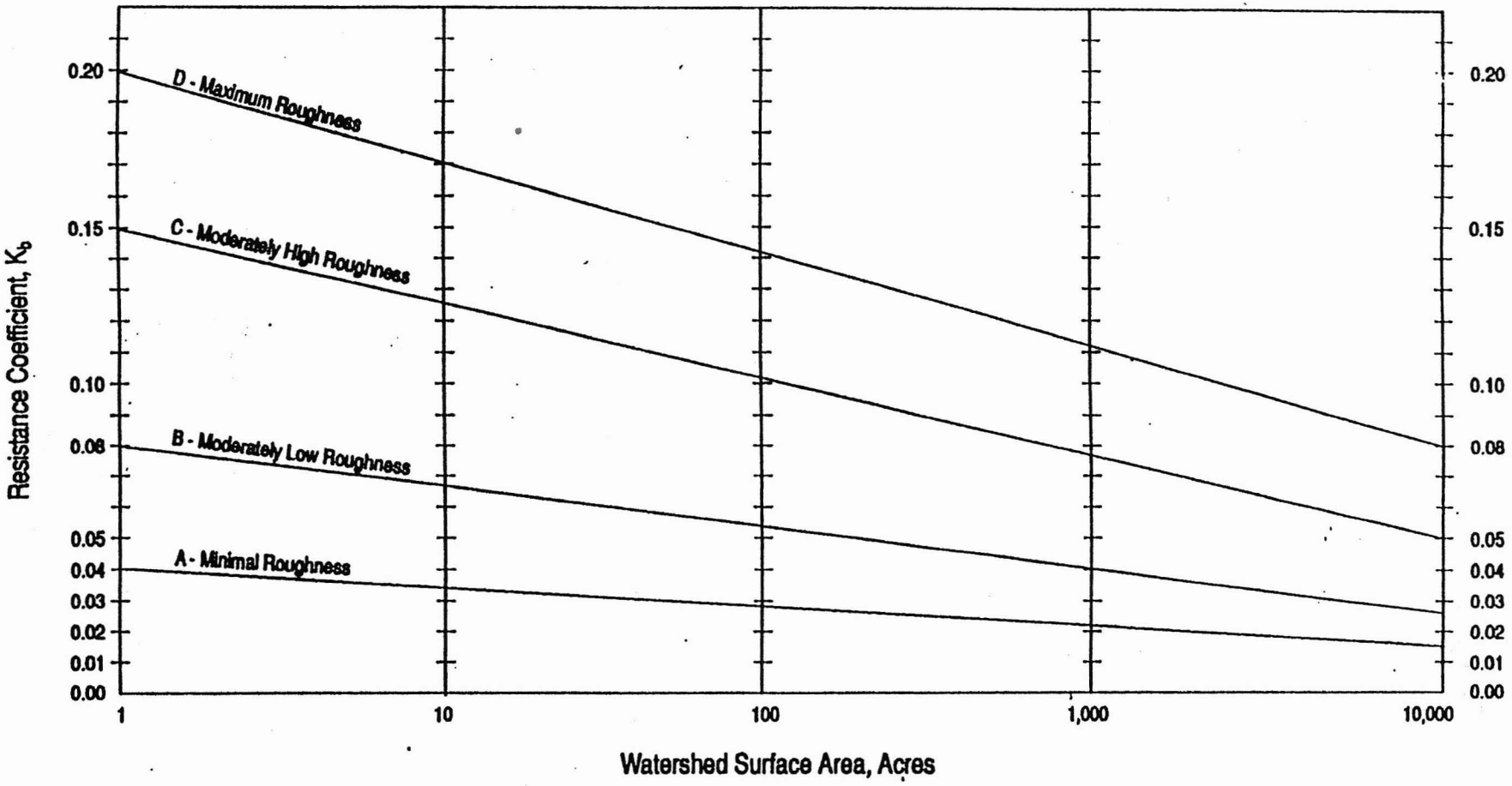



**Figure 5.5**

**Resistance Coefficient "$K_b$" as a Function of Watershed Size and Surface Roughness Characteristics**

**Table 5.1**
**Equation for Estimating $K_b$ in the Tc Equation**

| $K_b = m \log A + b$<br>Where A is drainage area, in acres | | | | |
|---|---|---|---|---|
| Type | Description | Typical Applications | Equation Parameters | |
| | | | m | b |
| A | Minimal roughness: Relatively smooth and/or well graded and uniform land surfaces. Surface runoff is sheet flow. | Commercial/ industrial areas<br>Residential area<br>Parks and golf courses | –0.00625 | 0.04 |
| B | Moderately low roughness: Land surfaces have irregularly spaced roughness elements that protrude from the surface but the overall character of the surface is relatively uniform. Surface runoff is predominately sheet flow around the roughness elements. | Agricultural fields<br>Pastures<br>Desert rangelands<br>Undeveloped urban lands | –0.01375 | 0.08 |
| C | Moderately high roughness: Land surfaces that have significant large- to medium-sized roughness elements and/or poorly graded land surfaces that cause the flow to be diverted around the roughness elements. Surface runoff is sheet flow for short distances draining into meandering drainage paths. | Hillslopes<br>Brushy alluvial fans<br>Hilly rangeland<br>Disturbed land, mining, etc.<br>Forests with underbrush | –0.025 | 0.15 |
| D | Maximum roughness: Rough land surfaces with torturous flow paths. Surface runoff is concentrated in numerous short flow paths that are often oblique to the main flow direction. | Mountains<br>Some wetlands | –0.030 | 0.20 |

Source: FCDMC Hydrology Manual

# Appendix C3
# Time of Concentration

**Time of Concentration - Subbasin B1 (General Storm)**

| Iteration No. | Channel Flow Segment: Channel d/s: Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Channel u/s: Flow Depth (ft) | Average Channel Flow Parameters: Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Travel Time: Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Time of Concentration (hr) | Subbasin Area (mi^2) | Total Basin Length (ft) | Storage Coefficient (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 34,873 | 0.0153 | 0.052 | 3651 | 1.814 | 1.05 | 1.43 | 0.0234 | 5.55 | 22470 | 1.12 | 0.42 | 1.54 | 4.089 | 28,939 | 1.044 |
| 2 | 3,197 | 0.0153 | 0.052 | 3651 | 0.433 | 1.05 | 0.74 | 0.0234 | 3.58 | 22470 | 1.74 | 0.42 | 2.16 | 4.089 | 28,939 | 1.519 |
| 3 | 3,253 | 0.0153 | 0.052 | 3651 | 0.437 | 1.05 | 0.75 | 0.0234 | 3.59 | 22470 | 1.74 | 0.42 | 2.15 | 4.089 | 28,939 | 1.516 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1600 | 1575 | 1630 | 0.0153 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2100 | 1575 | 22470 | 0.0234 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| Surface Description | | Range | | | | |
|---|---|---|---|---|---|---|
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.667 | 3150 | 2950 | 300 | 0.667 |
| Travel Time, Tsheet | hr | 0.13 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| Surface description | | Unpaved | | | | |
|---|---|---|---|---|---|---|
| Flow length, L | ft | 6169 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.138 | 2950 | 2100 | 6169 | 0.138 |
| Average velocity, V | ft/s | 6 | | | | |
| Travel Time, Tshallow | hr | 0.29 | | | | |
| Total Travel Time | hr | 0.42 | | | | |
| (Sheet+Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 6.00 | 0.0412 | 0.052 | 1.05 |

**Time of Concentration - Subbasin C1 (General Storm)**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 24,379 | 0.0163 | 0.034 | 6172 | 0.813 | 0.47 | 0.64 | 0.0355 | 6.13 | 16331 | 0.74 | 0.18 | 0.92 | 2.537 | 18,005 | 0.527 |
| 2 | 2,053 | 0.0163 | 0.034 | 6172 | 0.184 | 0.47 | 0.33 | 0.0355 | 3.91 | 16331 | 1.16 | 0.18 | 1.33 | 2.537 | 18,005 | 0.800 |
| 3 | 2,052 | 0.0163 | 0.034 | 6172 | 0.184 | 0.47 | 0.33 | 0.0355 | 3.91 | 16331 | 1.16 | 0.18 | 1.33 | 2.537 | 18,005 | 0.800 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1600 | 1570 | 1840 | 0.0163 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2150 | 1570 | 16331 | 0.0355 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | S |
| Land Slope, s | ft/ft | 0.620 | 2786 | 2600 | 300 | 0.620 |
| Travel Time, Tsheet | hr | 0.13 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description (paved or unpaved) | | Unpaved | | | | |
| Flow length, L | ft | 1374 | Elev1 | Elev2 | L | S |
| Watercourse slope, s | ft/ft | 0.328 | 2600 | 2150 | 1374 | 0.328 |
| Average velocity, V | ft/s | 9.25 | | | | |
| Travel Time, Tshallow | hr | 0.04 | | | | |
| Total Travel Time | hr | 0.18 | | | | |
| (Sheet+Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 6.25 | 0.1305 | 0.052 | 0.47 |

**Time of Concentration - Subbasin F**

| Iteration No. | Channel Flow Segment: Channel d/s[1] Discharge (cfs) | Bottom Slope[3] (ft/ft) | Manning's n[5] | Effective Basin Width (ft) | Flow Depth (ft) | Channel u/s[2] Flow Depth (ft) | Average Channel Flow Parameters: Average Depth (ft) | Average Slope[4] (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Travel Time: Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Time of Concentration (hr) | Subbasin Area (mi^2) | Total Basin Length (ft) | Storage Coefficient (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,590 | 0.0133 | 0.043 | 1650 | 0.43 | 0.45 | 0.44 | 0.0159 | 2.51 | 2510 | 0.28 | 0.71 | 0.99 | 0.15 | 3,970 | 0.856 |
| 2 | 551 | 0.0133 | 0.043 | 1650 | 0.23 | 0.45 | 0.34 | 0.0159 | 2.11 | 2510 | 0.33 | 0.71 | 1.04 | 0.15 | 3,970 | 0.907 |
| 3 | 529 | 0.0133 | 0.043 | 1650 | 0.22 | 0.45 | 0.33 | 0.0159 | 2.10 | 2510 | 0.33 | 0.71 | 1.04 | 0.15 | 3,970 | 0.908 |

1. Downstream segment of the channel flow segment.
2. Upstream segment of the channel flow segment. See Note-2 for flow depth at the upstream boundary.
3. Average slope at the downstream segment of the channel. See Note-1.
4. Average slope along the channel flow segment. See Note-1.
5. For composite urban-rural areas, an average of the rural Manning's n (n=0.052, see Appendix D.1) and urban Manning's n (n=0.034, see Appendix D.1) were used.

**NOTE-1:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.017 | 1760 | 1755 | 300 | 0.0167 |
| Travel Time, Tsheet | hr | 0.57 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description | | Unpaved | | | | |
| Flow length, L | ft | 1000 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.015 | 1755 | 1740 | 1000 | 0.015 |
| Average velocity, V | ft/s | 2 | | | | |
| Travel Time, Tshallow | hr | 0.14 | | | | |
| Total Travel Time | hr | 0.71 | | | | |
| Sheet and Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 2.00 | 0.0132 | 0.05 | 0.45 |

**Time of Concentration - Subbasin G**

| Iteration No. | Channel Flow Segment: Channel d/s: Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Channel u/s: Flow Depth (ft) | Average Channel Flow Parameters: Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Travel Time: Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Time of Concentration (hr) | Subbasin Area (mi^2) | Total Basin Length (ft) | Storage Coefficient (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4,324 | 0.0143 | 0.043 | 3230 | 0.51 | 0.44 | 0.47 | 0.0175 | 2.78 | 2850 | 0.29 | 0.71 | 0.99 | 0.52 | 4,150 | 0.440 |
| 2 | 2,638 | 0.0143 | 0.043 | 3230 | 0.38 | 0.44 | 0.41 | 0.0175 | 2.51 | 2850 | 0.31 | 0.71 | 1.02 | 0.52 | 4,150 | 0.455 |
| 3 | 2,580 | 0.0143 | 0.043 | 3230 | 0.37 | 0.44 | 0.40 | 0.0175 | 2.50 | 2850 | 0.32 | 0.71 | 1.03 | 0.52 | 4,150 | 0.456 |

**NOTE-1:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.017 | 1770 | 1765 | 300 | 0.0167 |
| Travel Time, Tsheet | hr | 0.57 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description | | Unpaved | | | | |
| Flow length, L | ft | 1000 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.015 | 1765 | 1750 | 1000 | 0.015 |
| Average velocity, V | ft/s | 2 | | | | |
| Travel Time, Tshallow | hr | 0.14 | | | | |
| Total Travel Time | hr | 0.71 | | | | |
| (Sheet and Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\ V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 2.00 | 0.0137 | 0.05 | 0.44 |

**Time of Concentration - Subbasin H**

| Iteration No. | Channel Flow Segment: Channel d/s: Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Channel u/s: Flow Depth (ft) | Average Channel Flow Parameters: Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Travel Time: Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Time of Concentration (hr) | Subbasin Area (mi^2) | Total Basin Length (ft) | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6,913 | 0.0173 | 0.043 | 2755 | 0.70 | 0.33 | 0.52 | 0.0227 | 3.35 | 12770 | 1.06 | 0.56 | 1.61 | 0.86 | 14,410 | 1.531 |
| 2 | 2,155 | 0.0173 | 0.043 | 2755 | 0.35 | 0.33 | 0.34 | 0.0227 | 2.54 | 12770 | 1.40 | 0.56 | 1.95 | 0.86 | 14,410 | 1.892 |
| 3 | 1,812 | 0.0173 | 0.043 | 2755 | 0.31 | 0.33 | 0.32 | 0.0227 | 2.46 | 12770 | 1.44 | 0.56 | 2.00 | 0.86 | 14,410 | 1.944 |
| 4 | 1,626 | 0.0173 | 0.043 | 2755 | 0.29 | 0.33 | 0.31 | 0.0227 | 2.41 | 12770 | 1.47 | 0.56 | 2.03 | 0.86 | 14,410 | 1.977 |

**NOTE-1:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.033 | 2045 | 2035 | 300 | 0.0333 |
| Travel Time, Tsheet | hr | 0.43 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description | | Unpaved | | | | |
| Flow length, L | ft | 1340 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.034 | 2035 | 1990 | 1340 | 0.0336 |
| Average velocity, V | ft/s | 3 | | | | |
| Travel Time, Tshallow | hr | 0.12 | | | | |
| Total Travel Time | hr | 0.56 | | | | |
| (Sheet and Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 3.00 | 0.0440 | 0.05 | 0.33 |

**Time of Concentration - Subbasin I**

| Iteration No. | Channel Flow Segment: Channel d/s: Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Channel u/s: Flow Depth (ft) | Average Channel Flow Parameters: Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Travel Time: Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Time of Concentration (hr) | Subbasin Area (mi^2) | Total Basin Length (ft) | Storage Coefficient (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,610 | 0.0250 | 0.043 | 3410 | 0.58 | 0.49 | 0.54 | 0.0250 | 3.62 | 12168 | 0.93 | 0.87 | 1.81 | 1.32 | 17,088 | 1.561 |
| 2 | 2,972 | 0.0250 | 0.043 | 3410 | 0.33 | 0.49 | 0.41 | 0.0250 | 3.03 | 12168 | 1.12 | 0.87 | 1.99 | 1.32 | 17,088 | 1.736 |
| 3 | 2,715 | 0.0250 | 0.043 | 3410 | 0.31 | 0.49 | 0.40 | 0.0250 | 2.98 | 12168 | 1.13 | 0.87 | 2.01 | 1.32 | 17,088 | 1.752 |
| 4 | 2,706 | 0.0250 | 0.043 | 3410 | 0.31 | 0.49 | 0.40 | 0.0250 | 2.98 | 12168 | 1.13 | 0.87 | 2.01 | 1.32 | 17,088 | 1.752 |

**NOTE-1:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.033 | 2110 | 2100 | 300 | 0.0333 |
| Travel Time, Tsheet | hr | 0.43 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description | | Unpaved | | | | |
| Flow length, L | ft | 4620 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.032 | 2100 | 1950 | 4620 | 0.0325 |
| Average velocity, V | ft/s | 2.9 | | | | |
| Travel Time, Tshallow | hr | 0.44 | | | | |
| Total Travel Time | hr | 0.87 | | | | |
| (Sheet and Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 2.90 | 0.0245 | 0.05 | 0.49 |

**Time of Concentration - Subbasin A1**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 9,727 | 0.0183 | 0.043 | 3345 | 0.75 | 0.58 | 0.66 | 0.0204 | 3.76 | 11021 | 0.81 | 0.21 | 1.02 | 0.963 | 12,277 | 0.763 |
| 2 | 3,697 | 0.0183 | 0.043 | 3345 | 0.42 | 0.58 | 0.50 | 0.0204 | 3.11 | 11021 | 0.99 | 0.21 | 1.20 | 0.963 | 12,277 | 0.905 |
| 3 | 3,244 | 0.0183 | 0.043 | 3345 | 0.39 | 0.58 | 0.48 | 0.0204 | 3.04 | 11021 | 1.01 | 0.21 | 1.22 | 0.963 | 12,277 | 0.923 |
| 4 | 3,197 | 0.0183 | 0.043 | 3345 | 0.39 | 0.58 | 0.48 | 0.0204 | 3.03 | 11021 | 1.01 | 0.21 | 1.22 | 0.963 | 12,277 | 0.925 |

**NOTE-1:**

| Elev1[5] | Elev2[5] | L | s[3] |
|---|---|---|---|
| 1620 | 1575 | 2458 | 0.0183 |

| Elev1[6] | Elev2[6] | L | s[4] |
|---|---|---|---|
| 1800 | 1575 | 11021 | 0.0204 |

3. Average slope at the downstream segment of the channel.
4. Average slope along the channel flow segment.
5. Use the USGS quad map to compute the channel bottom slope at the downstream end.
6. Use the USGS quad map to compute the channel bottom slope along the channel flow segment.

**NOTE-2:**

**Sheet Flow**

| Surface Description | | Range | | | | |
|---|---|---|---|---|---|---|
| Manning's n | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| 2-yr 24-hr precip, p2* | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.400 | 2020 | 1900 | 300 | 0.400 |
| Travel Time, Tsheet | hr | 0.16 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

*Precipitation depth, p2
Latitude: 33 27 North, Longitude: 111 38 West
From NOAA Atlas, $p_2$ = 1.4 in

**Shallow Concentrated Flow**

| Surface description | | Unpaved | | | | |
|---|---|---|---|---|---|---|
| Flow length, L | ft | 956 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.105 | 1900 | 1800 | 956 | 0.105 |
| Average velocity, V | ft/s | 5.25 | | | | |
| Travel Time, Tshallow | hr | 0.05 | | | | |
| Total Travel Time*** | hr | 0.21 | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

* Average land slope along shallow concentrated flow segment
** Use TR-55
*** Sheet and Shallow Concentrated Flow

**Upstream Boundary (Flow Depth)**

| Velocity* (ft/s) | Bottom** Slope (ft/ft) | Manning's n | Flow*** Depth (ft) |
|---|---|---|---|
| 5.25 | 0.0415 | 0.040 | 0.58 |

* Average velocity along shallow concentrated flow
** Average bottom slope at the downstream end of the shallow concentrated flow
*** Flow Depth was computed using the Manning's equation

**Time of Concentration - Subbasin B1**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 34,873 | 0.0153 | 0.052 | 3651 | 1.81 | 1.05 | 1.43 | 0.0234 | 5.55 | 22470 | 1.12 | 0.42 | 1.54 | 4.089 | 28,939 | 1.044 |
| 2 | 13,025 | 0.0153 | 0.052 | 3651 | 1.00 | 1.05 | 1.03 | 0.0234 | 4.45 | 22470 | 1.40 | 0.42 | 1.82 | 4.089 | 28,939 | 1.256 |
| 3 | 11,273 | 0.0153 | 0.052 | 3651 | 0.92 | 1.05 | 0.99 | 0.0234 | 4.33 | 22470 | 1.44 | 0.42 | 1.86 | 4.089 | 28,939 | 1.286 |
| 4 | 11,044 | 0.0153 | 0.052 | 3651 | 0.91 | 1.05 | 0.98 | 0.0234 | 4.31 | 22470 | 1.45 | 0.42 | 1.86 | 4.089 | 28,939 | 1.290 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1600 | 1575 | 1630 | 0.0153 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2100 | 1575 | 22470 | 0.0234 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| Surface Description | | Range | | | | |
|---|---|---|---|---|---|---|
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.667 | 3150 | 2950 | 300 | 0.667 |
| Travel Time, Tsheet | hr | 0.13 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\, s^{0.4}}$$

**Shallow Concentrated Flow**

| Surface description | | Unpaved | | | | |
|---|---|---|---|---|---|---|
| Flow length, L | ft | 6169 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.138 | 2950 | 2100 | 6169 | 0.138 |
| Average velocity, V | ft/s | 6 | | | | |
| Travel Time, Tshallow | hr | 0.29 | | | | |
| Total Travel Time (Sheet+Shallow Concentrated) | hr | 0.42 | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 6.00 | 0.0412 | 0.052 | 1.05 |

**Time of Concentration - Subbasin B2**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 18,689 | 0.0171 | 0.043 | 3643 | 1.08 | 0.40 | 0.74 | 0.0281 | 4.75 | 15231 | 0.89 | 0.47 | 1.36 | 1.359 | 17,781 | 1.157 |
| 2 | 3,872 | 0.0171 | 0.043 | 3643 | 0.42 | 0.40 | 0.41 | 0.0281 | 3.20 | 15231 | 1.32 | 0.47 | 1.79 | 1.359 | 17,781 | 1.567 |
| 3 | 3,010 | 0.0171 | 0.043 | 3643 | 0.36 | 0.40 | 0.38 | 0.0281 | 3.05 | 15231 | 1.39 | 0.47 | 1.86 | 1.359 | 17,781 | 1.632 |
| 4 | 2,907 | 0.0171 | 0.043 | 3643 | 0.35 | 0.40 | 0.38 | 0.0281 | 3.03 | 15231 | 1.40 | 0.47 | 1.87 | 1.359 | 17,781 | 1.641 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1600 | 1572 | 1642 | 0.0171 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2000 | 1572 | 15231 | 0.0281 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| Surface Description | | Range | | | | |
|---|---|---|---|---|---|---|
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.083 | 2145 | 2120 | 300 | 0.083 |
| Travel Time, Tsheet | hr | 0.30 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

| Surface description | | Unpaved | | | | |
|---|---|---|---|---|---|---|
| Flow length, L | ft | 2250 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.053 | 2120 | 2000 | 2250 | 0.053 |
| Average velocity, V | ft/s | 3.65 | | | | |
| Travel Time, Tshallow | hr | 0.17 | | | | |
| Total Travel Time | hr | 0.47 | | | | |
| (Sheet and Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 3.65 | 0.0548 | 0.052 | 0.40 |

**Time of Concentration - Subbasin C1**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 24,379 | 0.0163 | 0.034 | 6172 | 0.81 | 0.47 | 0.64 | 0.0355 | 6.13 | 16331 | 0.74 | 0.18 | 0.92 | 2.537 | 18,005 | 0.527 |
| 2 | 12,130 | 0.0163 | 0.034 | 6172 | 0.53 | 0.47 | 0.50 | 0.0355 | 5.21 | 16331 | 0.87 | 0.18 | 1.05 | 2.537 | 18,005 | 0.611 |
| 3 | 10,954 | 0.0163 | 0.034 | 6172 | 0.50 | 0.47 | 0.49 | 0.0355 | 5.10 | 16331 | 0.89 | 0.18 | 1.07 | 2.537 | 18,005 | 0.623 |
| 4 | 10,683 | 0.0163 | 0.034 | 6172 | 0.50 | 0.47 | 0.48 | 0.0355 | 5.07 | 16331 | 0.89 | 0.18 | 1.07 | 2.537 | 18,005 | 0.626 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1600 | 1570 | 1840 | 0.0163 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2150 | 1570 | 16331 | 0.0355 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L - | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | S |
| Land Slope, s | ft/ft | 0.620 | 2786 | 2600 | 300 | 0.620 |
| Travel Time, Tsheet | hr | 0.13 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\, s^{0.4}}$$

**Shallow Concentrated Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description | | Unpaved | | | | |
| Flow length, L | ft | 1374 | Elev1 | Elev2 | L | S |
| Watercourse slope, s | ft/ft | 0.328 | 2600 | 2150 | 1374 | 0.328 |
| Average velocity, V | ft/s | 9.25 | | | | |
| Travel Time, Tshallow | hr | 0.04 | | | | |
| Total Travel Time | hr | 0.18 | | | | |
| (Sheet+Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 9.25 | 0.1305 | 0.052 | 0.85 |

**Time of Concentration - Subbasin D1**

| Iteration No. | Channel Flow Segment | | | | | | | | | | Travel Time | | Time of Concentration | Subbasin Area | Total Basin Length | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Channel d/s | | | | | Channel u/s | Average Channel Flow Parameters | | | | Channel Flow | Sheet and Shallow Concentrated Flow | | | | |
| | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | (hr) | (hr) | (hr) | (mi^2) | (ft) | (hr) |
| 1 | 12,072 | 0.0204 | 0.043 | 2130 | 1.09 | 0.75 | 0.92 | 0.0337 | 6.00 | 12694 | 0.59 | 0.18 | 0.77 | 1.171 | 13,902 | 0.551 |
| 2 | 5,524 | 0.0204 | 0.043 | 2130 | 0.68 | 0.75 | 0.72 | 0.0337 | 5.08 | 12694 | 0.69 | 0.18 | 0.88 | 1.171 | 13,902 | 0.635 |
| 3 | 4,833 | 0.0204 | 0.043 | 2130 | 0.63 | 0.75 | 0.69 | 0.0337 | 4.96 | 12694 | 0.71 | 0.18 | 0.90 | 1.171 | 13,902 | 0.649 |

**NOTE-1:**

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 1620 | 1572 | 2351 | 0.0204 |

1. Use the USGS quad map to compute the channel bottom slope d/s

| Elev1[1] | Elev2[1] | L | s[1] |
|---|---|---|---|
| 2000 | 1572 | 12694 | 0.0337 |

1. Use the USGS quad map to compute the channel bottom slope - channel flow

**NOTE-2:**

**Sheet Flow**

| | | | | | | |
|---|---|---|---|---|---|---|
| Surface Description | | Range | | | | |
| Manning's roughness coefficient | | 0.13 | | | | |
| Flow Length, L | ft | 300 | | | | |
| Two-year 24-hour rainfall, p2 | in | 1.4 | Elev1 | Elev2 | L | s |
| Land Slope, s | ft/ft | 0.400 | 2470 | 2350 | 300 | 0.400 |
| Travel Time, Tsheet | hr | 0.16 | | | | |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\,s^{0.4}}$$

**Shallow Concentrated Flow**

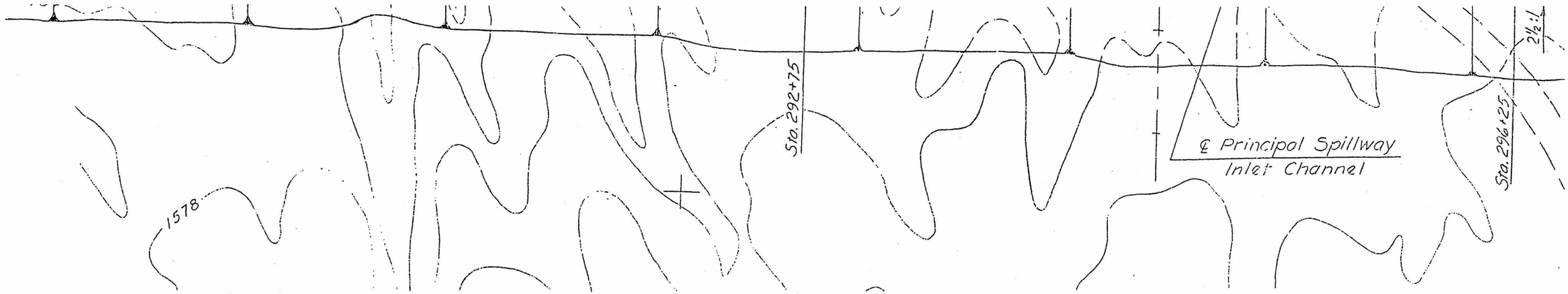
| | | | | | | |
|---|---|---|---|---|---|---|
| Surface description (paved or unpaved) | | Unpaved | | | | |
| Flow length, L | ft | 908 | Elev1 | Elev2 | L | s |
| Watercourse slope, s | ft/ft | 0.385 | 2350 | 2000 | 908 | 0.385 |
| Average velocity, V | ft/s | 10.1 | | | | |
| Travel Time, Tshallow | hr | 0.02 | | | | |
| Total Travel Time | hr | 0.18 | | | | |
| (Sheet+Shallow Concentrated) | | | | | | |

$$T_{shallow} = \frac{L}{3600\,V}$$

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 10.10 | 0.1818 | 0.052 | 0.75 |

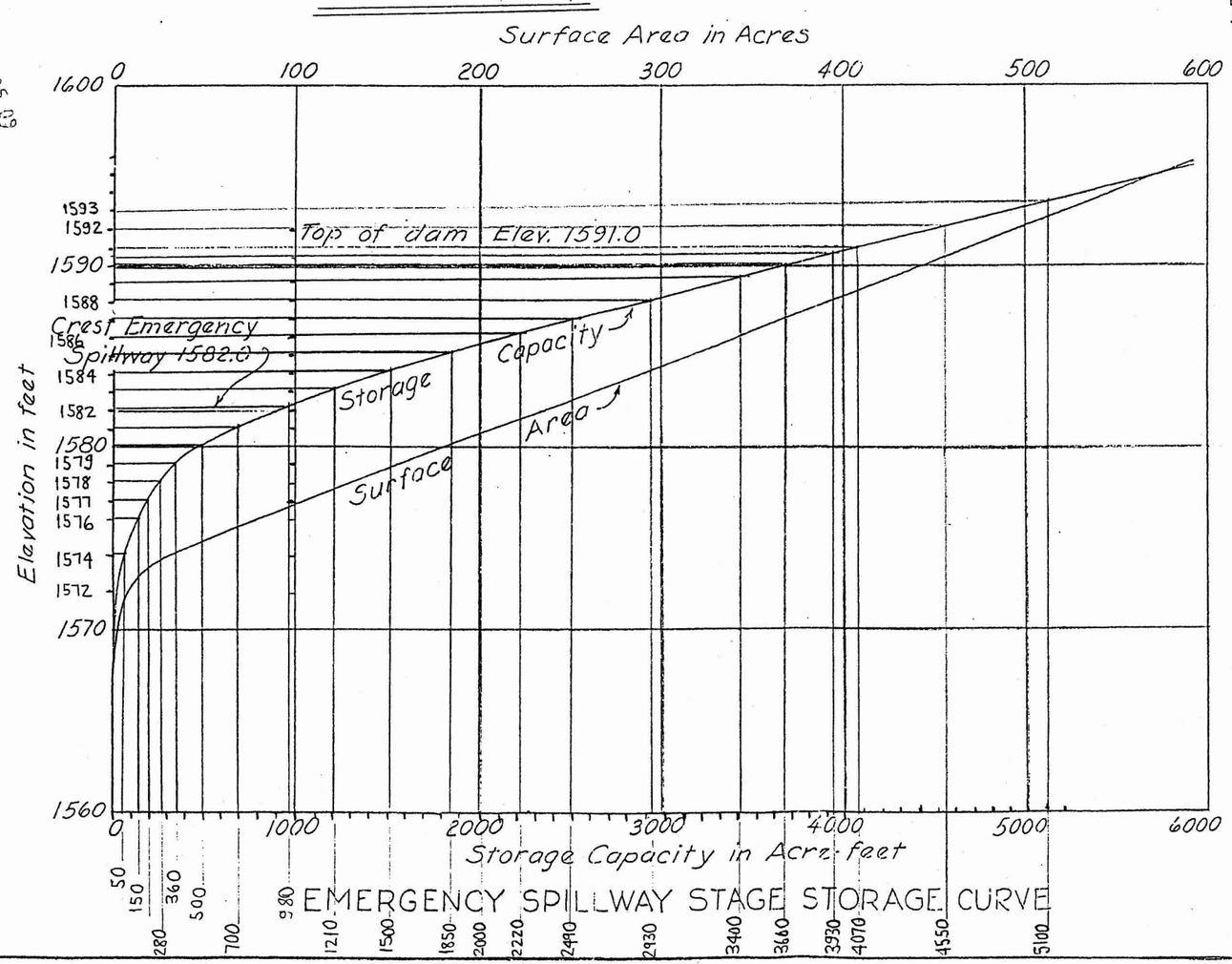
# Appendix C4
# Stage-Storage and Stage-Discharge Functions



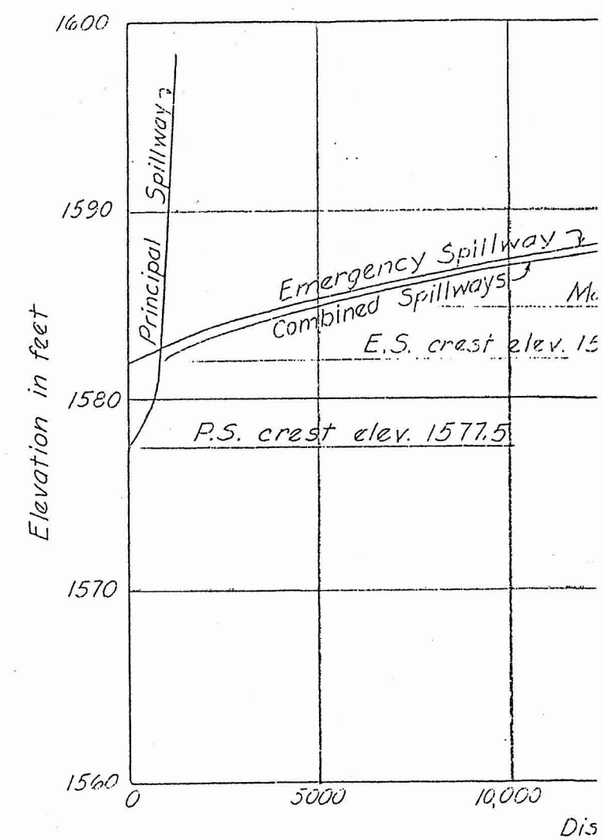

~ PLAN ~

50 0 50 100
SCALE IN FEET

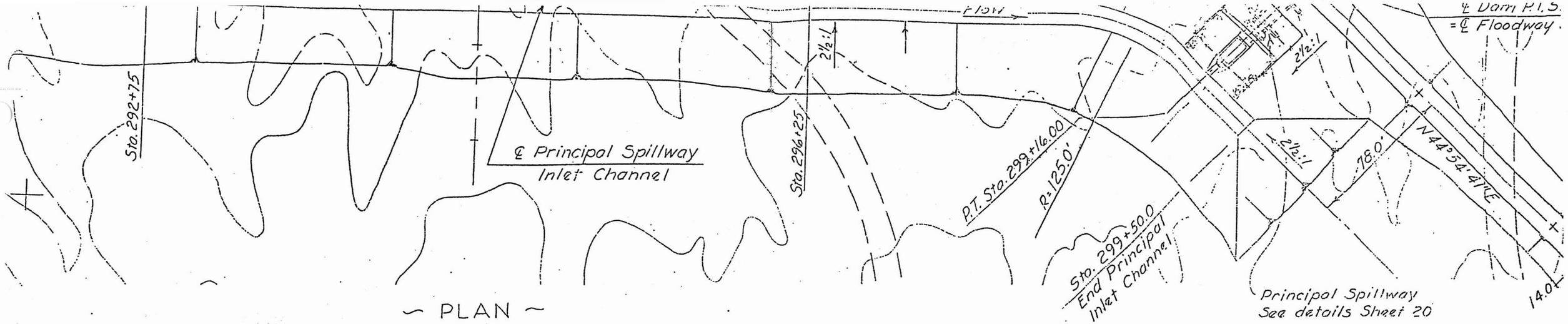
SCS AS-BUILT




EMERGENCY SPILLWAY STAGE STORAGE CURVE



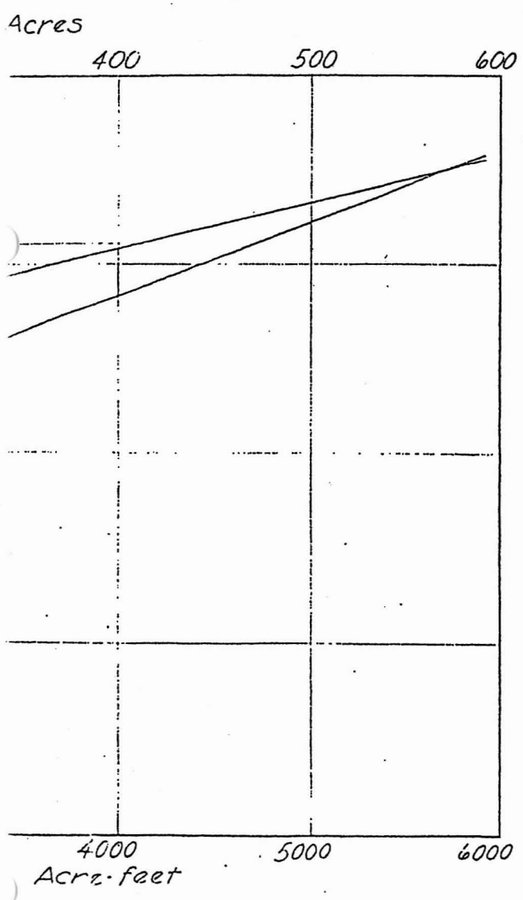

SPILLWAY STA



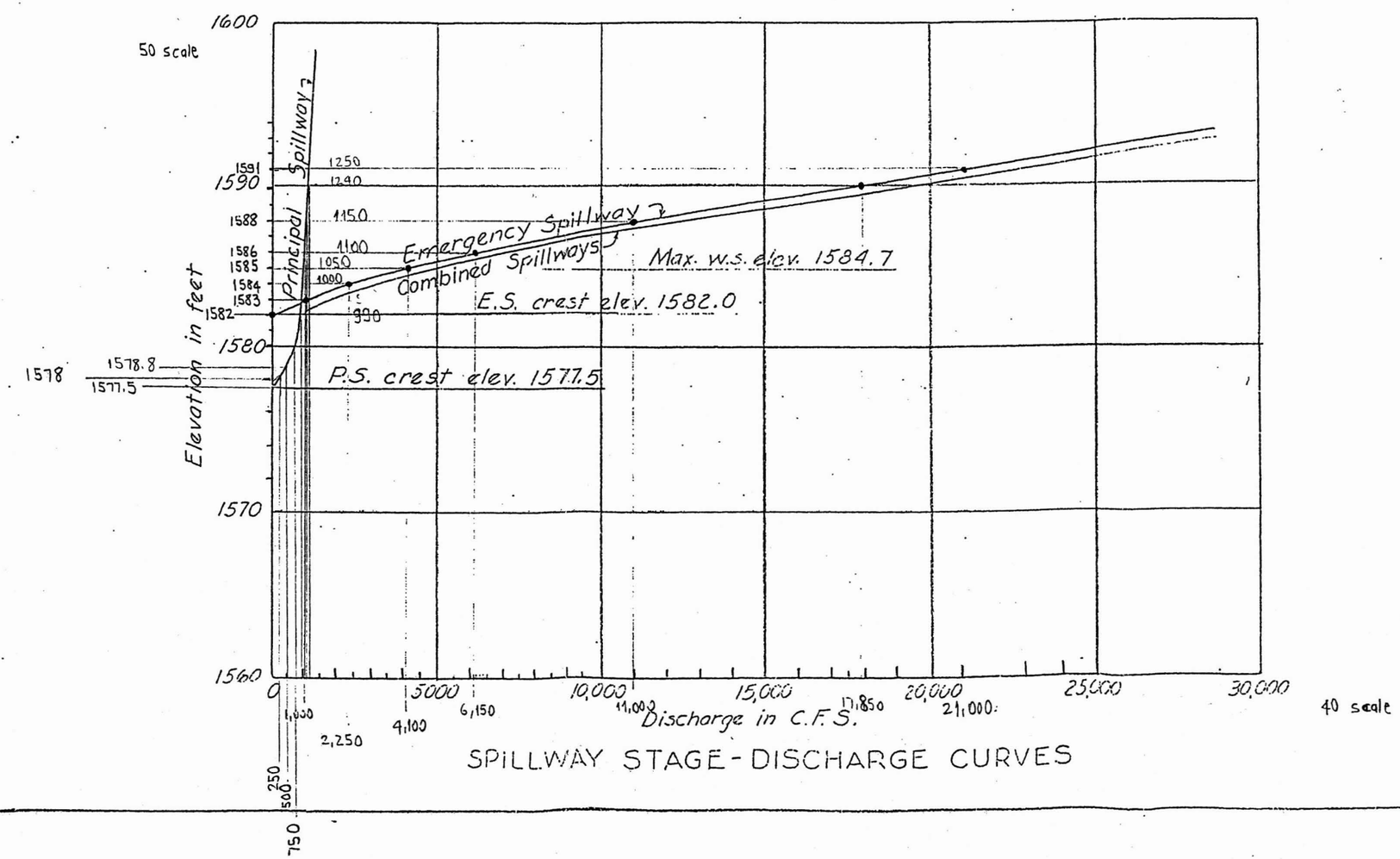

~ PLAN ~

50 0 50 100
SCALE IN FEET

SCS ASBUILT




GE STORAGE CURVE




SPILLWAY STAGE-DISCHARGE CURVES

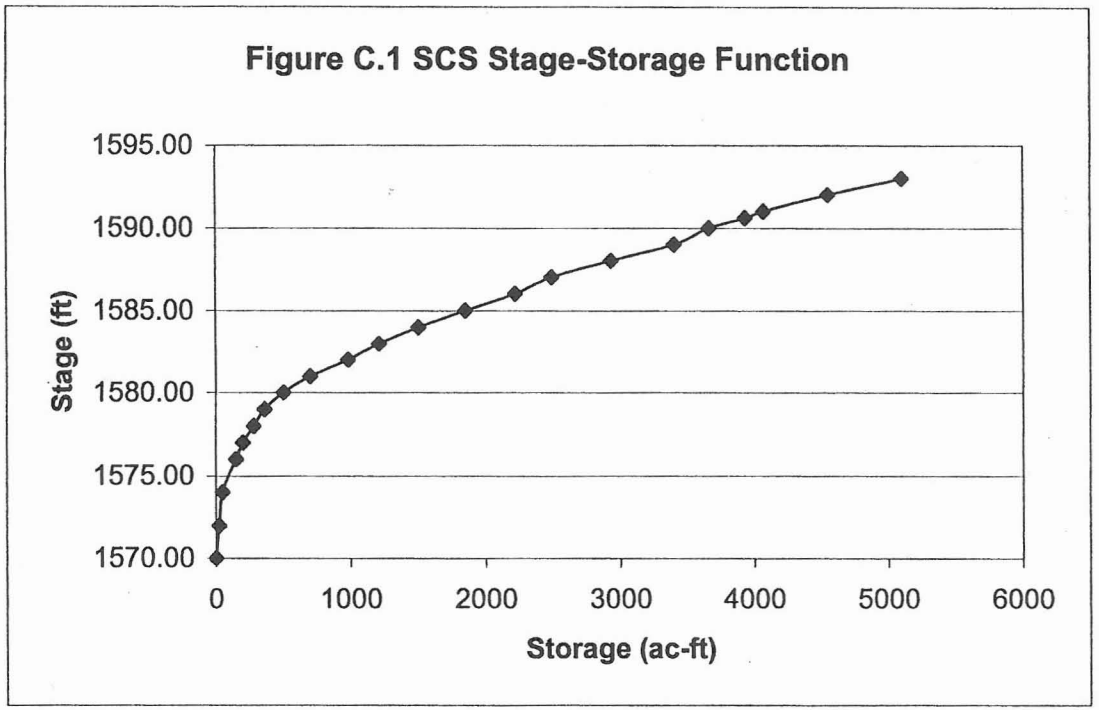
U.

Designed.
Drawn___
Traced__
Checked..

**SCS Stage-Storage Function**

| Storage (ac-ft) | Stage NGVD 29 (ft) |
|---|---|
| 0 | 1570.00 |
| 25 | 1572.00 |
| 50 | 1574.00 |
| 150 | 1576.00 |
| 200 | 1577.00 |
| 280 | 1578.00 |
| 360 | 1579.00 |
| 500 | 1580.00 |
| 700 | 1581.00 |
| 980 | 1582.00 |
| 1210 | 1583.00 |
| 1500 | 1584.00 |
| 1850 | 1585.00 |
| 2220 | 1586.00 |
| 2490 | 1587.00 |
| 2930 | 1588.00 |
| 3400 | 1589.00 |
| 3660 | 1590.00 |
| 3930 | 1590.60 |
| 4070 | 1591.00 |
| 4550 | 1592.00 |
| 5100 | 1593.00 |

Source: SCS As-built plans (1983).

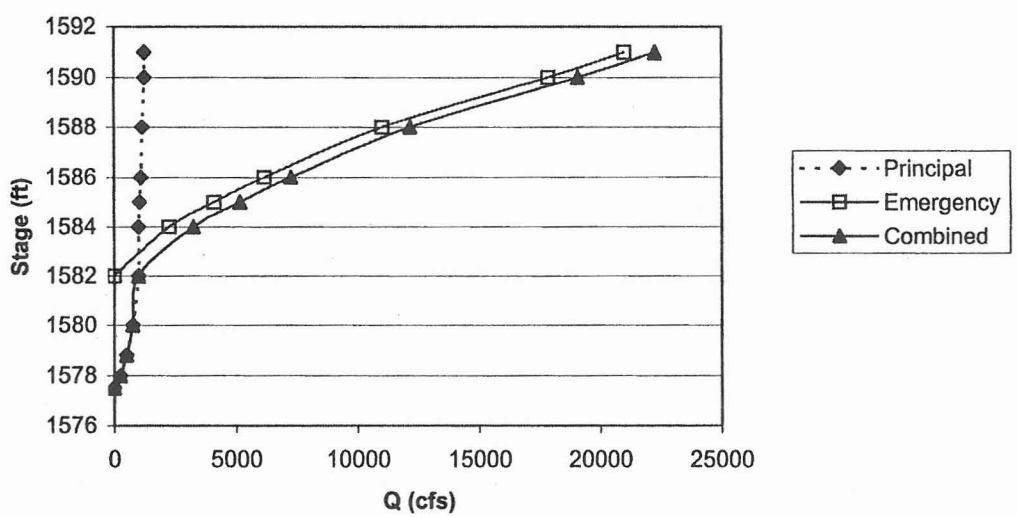


**SCS Stage-Discharge Function**

| Principal Spillway* | | Emergency Spillway* | | Combined Spillway | |
|---|---|---|---|---|---|
| Q (cfs) | Stage (ft) | Q (cfs) | Stage (ft) | Q (cfs) | Stage NGVD 29 (ft) |
| 0 | 1577.5 | | | 0 | 1577.5 |
| 250 | 1578 | | | 250 | 1578 |
| 500 | 1578.8 | | | 500 | 1578.8 |
| 750 | 1580 | | | 750 | 1580 |
| 990 | 1582 | 0 | 1582 | 990 | 1582 |
| 1000 | 1584 | 2250 | 1584 | 3250 | 1584 |
| 1050 | 1585 | 4100 | 1585 | 5150 | 1585 |
| 1100 | 1586 | 6150 | 1586 | 7250 | 1586 |
| 1150 | 1588 | 11000 | 1588 | 12150 | 1588 |
| 1240 | 1590 | 17850 | 1590 | 19090 | 1590 |
| 1250 | 1591 | 21000 | 1591 | 22250 | 1591 |

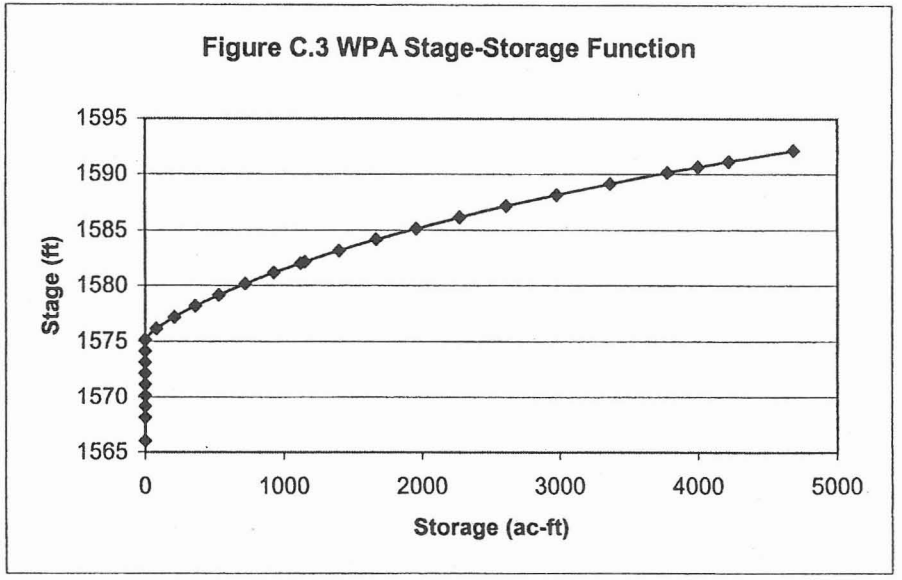
* SCS as-built plans (1983)

**Figure C.2 SCS Stage-Discharge Function**



**WPA Stage-Storage Function**

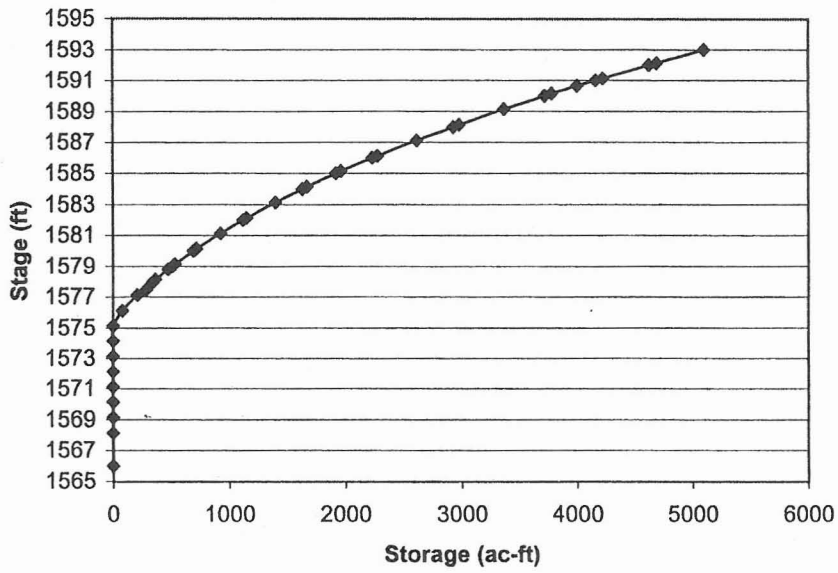
| Storage (ac-ft) | Stage NAVD 88 (ft) | Stage NGVD 29 (ft) | Remarks |
|---|---|---|---|
| 0 | 1567.86 | 1566.00 | |
| 0 | 1570.00 | 1568.14 | |
| 0 | 1571.00 | 1569.14 | |
| 0 | 1572.00 | 1570.14 | |
| 0 | 1573.00 | 1571.14 | |
| 0 | 1574.00 | 1572.14 | |
| 0 | 1575.00 | 1573.14 | |
| 0 | 1576.00 | 1574.14 | |
| 0 | 1577.00 | 1575.14 | |
| 81 | 1578.00 | 1576.14 | |
| 211 | 1579.00 | 1577.14 | |
| 363 | 1580.00 | 1578.14 | |
| 533 | 1581.00 | 1579.14 | |
| 719 | 1582.00 | 1580.14 | |
| 925 | 1583.00 | 1581.14 | |
| 1120 | 1583.86 | 1582.00 | Spillway Crest |
| 1152 | 1584.00 | 1582.14 | |
| 1399 | 1585.00 | 1583.14 | |
| 1668 | 1586.00 | 1584.14 | |
| 1960 | 1587.00 | 1585.14 | |
| 2275 | 1588.00 | 1586.14 | |
| 2615 | 1589.00 | 1587.14 | |
| 2978 | 1590.00 | 1588.14 | |
| 3366 | 1591.00 | 1589.14 | |
| 3780 | 1592.00 | 1590.14 | |
| 4000 | 1592.50 | 1590.64 | Minimum Top of Dam |
| 4220 | 1593.00 | 1591.14 | |
| 4687 | 1594.00 | 1592.14 | |



**DMJM+HARRIS Stage-Storage Data**

| Storage (ac-ft) | Stage NGVD 29 (ft) | Remarks |
|---|---|---|
| 0 | 1566.0 | |
| 0 | 1568.1 | |
| 0 | 1569.1 | |
| 0 | 1570.1 | |
| 0 | 1571.1 | |
| 0 | 1572.1 | |
| 0 | 1573.1 | |
| 0 | 1574.1 | |
| 0 | 1575.1 | |
| 81 | 1576.1 | |
| 211 | 1577.1 | |
| 287 | 1577.5 | |
| 346 | 1578.0 | |
| 363 | 1578.1 | |
| 475 | 1578.8 | |
| 509 | 1579.0 | |
| 533 | 1579.1 | |
| 693 | 1580.0 | |
| 719 | 1580.1 | |
| 925 | 1581.1 | |
| 1120 | 1582.0 | Spillway Crest |
| 1152 | 1582.1 | |
| 1399 | 1583.1 | |
| 1631 | 1584.0 | |
| 1668 | 1584.1 | |
| 1919 | 1585.0 | |
| 1960 | 1585.1 | |
| 2231 | 1586.0 | |
| 2275 | 1586.1 | |
| 2615 | 1587.1 | |
| 2927 | 1588.0 | |
| 2978 | 1588.1 | |
| 3366 | 1589.1 | |
| 3722 | 1590.0 | |
| 3780 | 1590.1 | |
| 4000 | 1590.6 | Minimum Top of Dam |
| 4158 | 1591.0 | |
| 4220 | 1591.1 | |
| 4622 | 1592.0 | |
| 4687 | 1592.1 | |
| 5100 | 1593.0 | |

**Figure C.4 DMJM+HARRIS Stage-Storage Function**



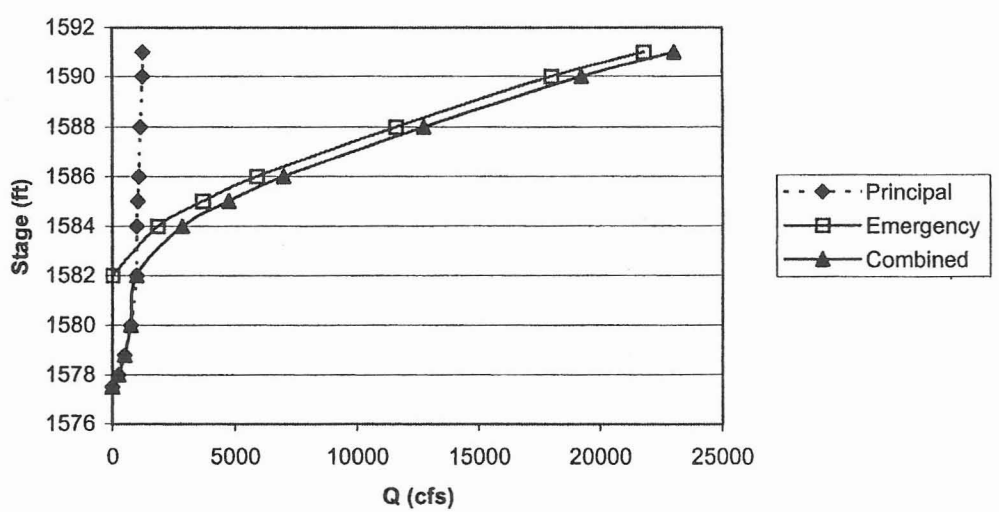
**DMJM+HARRIS Stage-Discharge Function**

| Principal Spillway* | | Emergency Spillway** | | Combined Spillway | |
|---|---|---|---|---|---|
| Q (cfs) | Stage (ft) | Q (cfs) | Stage (ft) | Q (cfs) | Stage NGVD 29 (ft) |
| 0 | 1577.5 | | | 0 | 1577.5 |
| 250 | 1578 | | | 250 | 1578 |
| 500 | 1578.8 | | | 500 | 1578.8 |
| 750 | 1580 | | | 750 | 1580 |
| 990 | 1582 | 0 | 1582 | 990 | 1582 |
| 1000 | 1584 | 1860 | 1584 | 2860 | 1584 |
| 1050 | 1585 | 3700 | 1585 | 4750 | 1585 |
| 1100 | 1586 | 5900 | 1586 | 7000 | 1586 |
| 1150 | 1588 | 11600 | 1588 | 12750 | 1588 |
| 1240 | 1590 | 18000 | 1590 | 19240 | 1590 |
| 1250 | 1591 | 21800 | 1591 | 23050 | 1591 |

* SCS as-built plans

** See Section 4.8

**Figure C.5 DMJM+HARRIS Stage-Discharge Function**



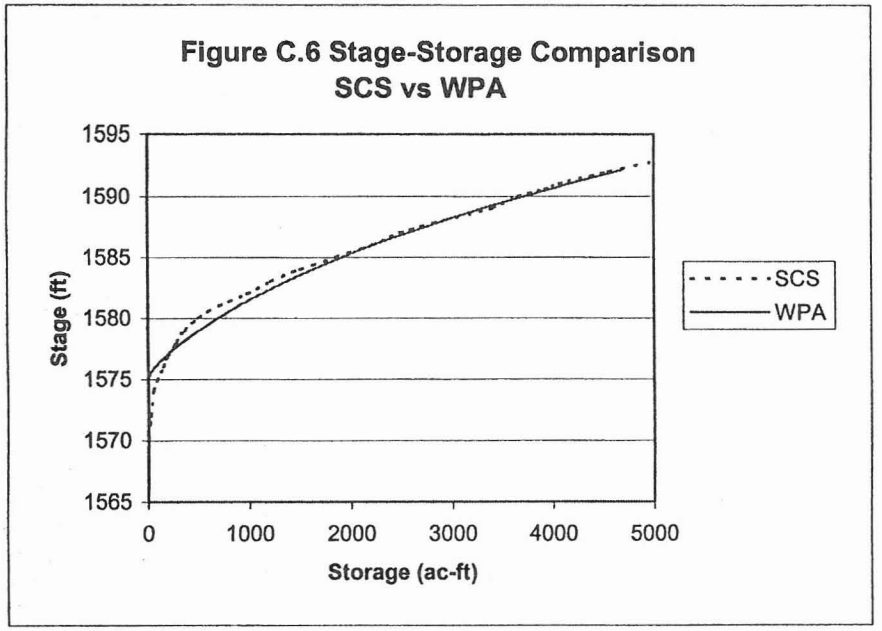


Figure C.6 Stage-Storage Comparison
SCS vs WPA
1595
1590
1585
1580
1575
1570
1565
Stage (ft)
0
1000
2000
3000
4000
5000
Storage (ac-ft)
SCS
WPA

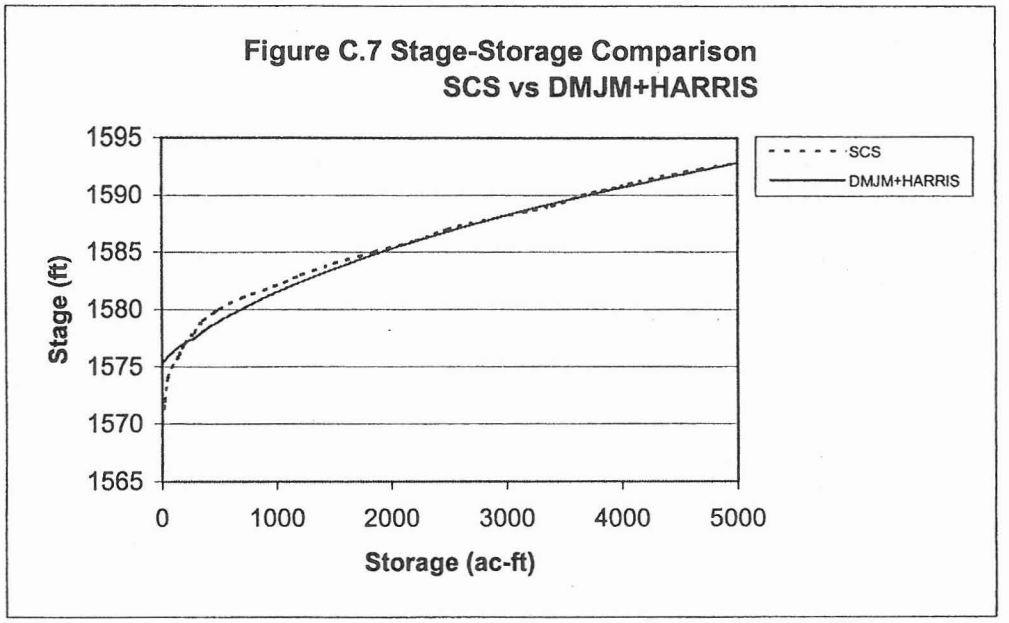


Figure C.7 Stage-Storage Comparison
SCS vs DMJM+HARRIS
1595
1590
1585
1580
1575
1570
1565
Stage (ft)
0
1000
2000
3000
4000
5000
Storage (ac-ft)
SCS
DMJM+HARRIS

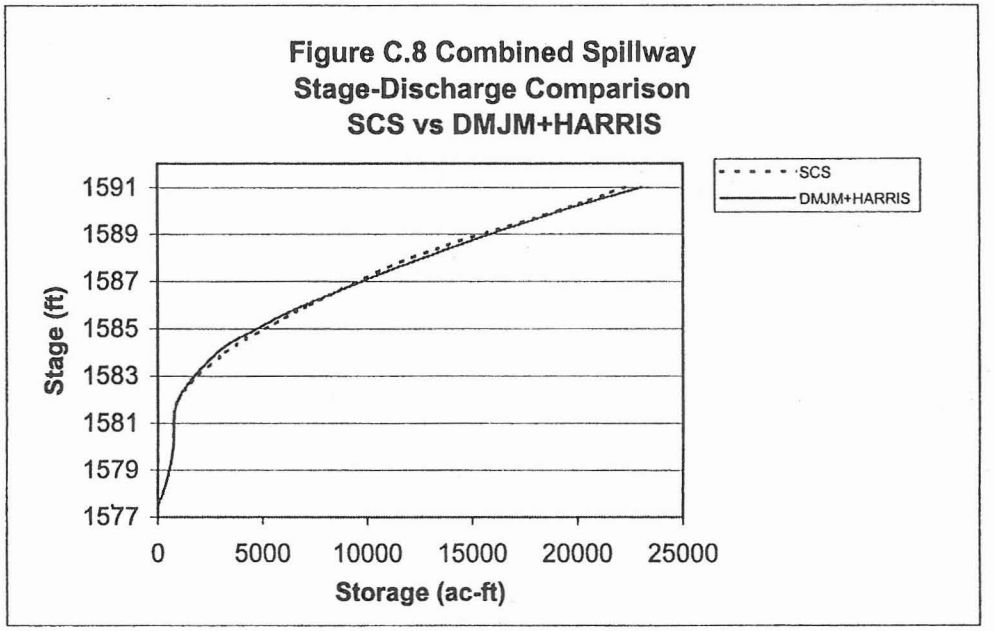


Figure C.8 Combined Spillway
Stage-Discharge Comparison
SCS vs DMJM+HARRIS
1591
1589
1587
1585
1583
1581
1579
1577
Stage (ft)
0
5000
10000
15000
20000
25000
Storage (ac-ft)
SCS
DMJM+HARRIS

## Tuncok, Kaan

**From:** Rick Hiner [RHiner@woodpatel.com]
**Sent:** Tuesday, August 21, 2001 5:12 PM
**To:** 'Kaan Tuncok @ DMJM+Harris'
**Cc:** 'Jeff Minch @ DMJM+Harris'
**Subject:** Questions about Spook Hill

Kaan,

I will now attempt to answer several of the questions you have asked over the past few weeks. I apologize for the delay in responding.

* Principal Spillway Rating Curve (computational basis and the rating curve).
Please refer to the Excel spreadsheet files I emailed to you on 8/9/01 (I think I had to resend it on 8/14/01 because you had trouble receiving it).

* The basis of your sediment elevation. (I would appreciate if you can provide a brief description for our files).
The sediment volume from the original design was 271 acre-feet. Using the new 2' contour information, it was determined that this would fill the basin to elevation 1577.2.

* The basis of the stage-storage relationship developed for the Spook Hill FRS.
The stage-storage relation ship was based on the new 2' contour data which was developed for the Spook Hill ADMP project. This data matched almost exactly with data developed by McLain-Harbors in 1995 for another FCD contract (their survey was limited to the FRS structures).

* In relation to the Signal Butte Floodway capacity at its downstream end, you have indicated in your most recent e-mail that as-built plans show a 0.0156 ft/ft channel bottom slope. In your most recent HEC-1 model that you have sent us on May 24th you have used the old slope of 0.0146 ft/ft. I would like to know if you have revised your HEC-1 or not? Also whether or not the other segments of the Floodway have been revised using the as-built plans? And finally I would appreciate if we can get a copy of the as-built plans along the Signal Butte Floodway.
As we discussed when I visited your office last week, there is a relatively short segment of the Signal Butte Floodway just upstream of the outfall into the Spook Hill FRS that is at a slope of 0.0156 ft/ft. Upstream of this segment is a longer segment which is at a slope of 0.0146 ft/ft. In our HEC-1 model, we did not attempt to break all of our routings at each small change in longitudinal slope, especially if the change was relatively insignificant.
The HEC-1 model that I sent you is the most recent existing condition model. I would be happy to supply you with a set of the as-built plans for the Signal Butte Floodway but I think I remember you saying that you have already obtained them from another source. If you still need them, let me know and I will send them over to you immediately so you can have them duplicated.

* Land Use upstream of the Spook Hill FRS, between Signal Butte Floodway outlet and Bulldog Floodway outlet. For the existing conditions hydrology report, we have used the City of Mesa Zoning Plans, and the Landiscor Maps within the Maricopa County Limits. There are certain segments upstream of the Spook Hill FRS, that are not clearly zoned. I would like to know if you have a hard copy or electronic zoning map that you have used for your HEC-1 model.
We also used the City of Mesa zoning plans and the Landiscor Maps within

Maricopa County. We also have the Apache Junction General Plan for the Pinal County areas. All of our zoning information is hard copy, we did not use any electronic zoning information for our model.

I hope that this answers all of your questions. Please email me if you have any additional questions and I should be able to respond much more quickly this time.

Sincerely,

Richard L Hiner, P.E.
Project Engineer/Manager
Wood, Patel & Associates, Inc.
2051 West Northern Avenue, Suite 100
Phoenix, Arizona 85021
Voice: (602) 335-8500 fax: (602) 335-8580
email: rhiner@woodpatel.com
web page: www.woodpatel.com

This electronic communication and its attachments may contain confidential information. They are forwarded to you without passing through our standard review process. Design data and recommendations included herein should not be used for final design, they are preliminary - NOT FOR CONSTRUCTION.
If you have received this information in error, please notify the sender immediately.

| Elevation (ft NAVD 1988) | Gage Height (feet) | Surface Area (acres) | Storage (ac-ft) | Sediment (ac-ft) | Storage (act. ac-ft) | | |
|---|---|---|---|---|---|---|---|
| 1567.86 | 0.00 | 0 | 0 | 271 | 0 | Invert of P.O. | |
| 1570 | 2.14 | 1 | 0.44 | 271 | 0 | | |
| 1571 | 3.14 | 6 | 4 | 271 | 0 | | |
| 1572 | 4.14 | 11 | 13 | 271 | 0 | | |
| 1573 | 5.14 | 20 | 29 | 271 | 0 | | |
| 1574 | 6.14 | 34 | 55 | 271 | 0 | | |
| 1575 | 7.14 | 51 | 98 | 271 | 0 | | |
| 1576 | 8.14 | 73 | 160 | 271 | 0 | | |
| 1577 | 9.14 | 96 | 245 | 271 | 0 | | |
| 1578 | 10.14 | 119 | 352 | 271 | 81 | | |
| 1579 | 11.14 | 141 | 482 | 271 | 211 | | |
| 1580 | 12.14 | 161 | 634 | 271 | 363 | | |
| 1581 | 13.14 | 178 | 804 | 271 | 533 | | |
| 1582 | 14.14 | 195 | 990 | 271 | 719 | | |
| 1583 | 15.14 | 216 | 1196 | 271 | 925 | | |
| 1583.86 | 16.00 | 234 | 1391 | 271 | 1120 | spillway crest | |
| 1584 | 16.14 | 237 | 1423 | 271 | 1152 | | |
| 1585 | 17.14 | 258 | 1670 | 271 | 1399 | | |
| 1586 | 18.14 | 281 | 1939 | 271 | 1668 | | |
| 1587 | 19.14 | 303 | 2231 | 271 | 1960 | | |
| 1588 | 20.14 | 327 | 2546 | 271 | 2275 | | |
| 1589 | 21.14 | 351 | 2886 | 271 | 2615 | | |
| 1590 | 22.14 | 376 | 3249 | 271 | 2978 | | |
| 1591 | 23.14 | 401 | 3637 | 271 | 3366 | | |
| 1592 | 24.14 | 427 | 4051 | 271 | 3780 | | |
| 1592.5 | 24.64 | 440 | 4271 | 271 | 4000 | minimum top of dam | |
| 1593 | 25.14 | 453 | 4491 | 271 | 4220 | | |
| 1594 | 26.14 | 481 | 4958 | 271 | 4687 | | |

Prepared by T. W. Lehman
March 24, 1997

Source: McClain Harbors topography and DTM from FCD Contract No. 93-51

# APPENDIX D

## White Papers

# Appendix D1

## Time of Concentration
## A Modification of the TR-55 Methodology

# TIME OF CONCENTRATION
## A MODIFICATION OF THE TR-55 METHODOLOGY

**ABSTRACT:** A new numerical procedure is presented for computing the time of concentration hydrologic variable. The proposed methodology combines the procedures and guidelines presented in the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS) Technical Release 55 (TR-55) with a computational algorithm developed by DMJM+HARRIS. Using a unit width approach, the algorithm iteratively defines the average channel flow parameters to determine the channel element travel time and ultimately the time of concentration for the contributing watershed. The proposed methodology should only be applied to extreme flood events where the natural watercourse does not have capacity to contain the flood flows and wide shallow flooding would occur. Numerical examples are provided for representative urban and rural watersheds.

## INTRODUCTION

While developing probable maximum flood (PMF) hydrology for the Spook Hill Floodwater Retarding Structure (FRS) in support of the Red Mountain Freeway design between Power Road and University Drive, it became apparent that the time of concentration variable had the most significant impact on peak flow estimates. The original design by the NRCS used an empirical relationship that defined average velocity as a function of channel slope. The draft PMF hydrology developed by DMJM+HARRIS used an empirical equation, with some procedural modifications from Papadakis and Kazan as defined in the Flood Control District of Maricopa County's (FCDMC) Hydrology Manual. The PMF peak flow estimates resulting from the two empirical methods differed significantly.

Subsequent to the review of the draft PMF hydrology by the Arizona Department of Water Resources (ADWR), NRCS, FCDMC, and the Arizona Department of Transportation (ADOT), the agencies agreed to utilize the TR-55 methodology to define the time of concentration since the parameters are more easily documented based on field conditions. DMJM+HARRIS performed a field reconnaissance on July 11, 2001 with ADWR and NRCS representatives to review the contributing watershed and the proposed methodology presented in this white paper. Both agencies agreed the proposed methodology would be an acceptable approach for defining the time of concentration for the Spook Hill FRS inflow design flood.

This paper is the first in a series of white papers which will be developed in support of the design of the Red Mountain Freeway from Power Road to University Drive. Additional white papers will be developed to resolve specific technical issues as the need arises. The purpose of this first paper is to define the procedures and guidelines that will be used to compute the PMF time of concentration for the Spook Hill FRS watershed.

## FORMULATION OF COMPUTATIONAL ALGORITHM

The TR-55 time of concentration methodology is applied by adding the computed travel times for sheet, shallow concentrated and channel flow segments for a subbasin or contributing watershed. An example subbasin delineation for the Spook Hill FRS is presented as Figure 1. The procedures and guidelines provided in TR-55 were used to compute the travel time for the sheet and shallow concentrated flow components of the subbasin.

Ⓐ Sheet Flow

Length= 300 ft

Slope= 0.667 ft/ft

n= 0.13

Ⓑ Shallow Concentrated Flow

Length= 6,075 ft

Slope= 0.132 ft/ft

Ⓒ Channel Flow

Length= 22,475 ft

Slope= 0.0231 ft/ft

n= 0.052

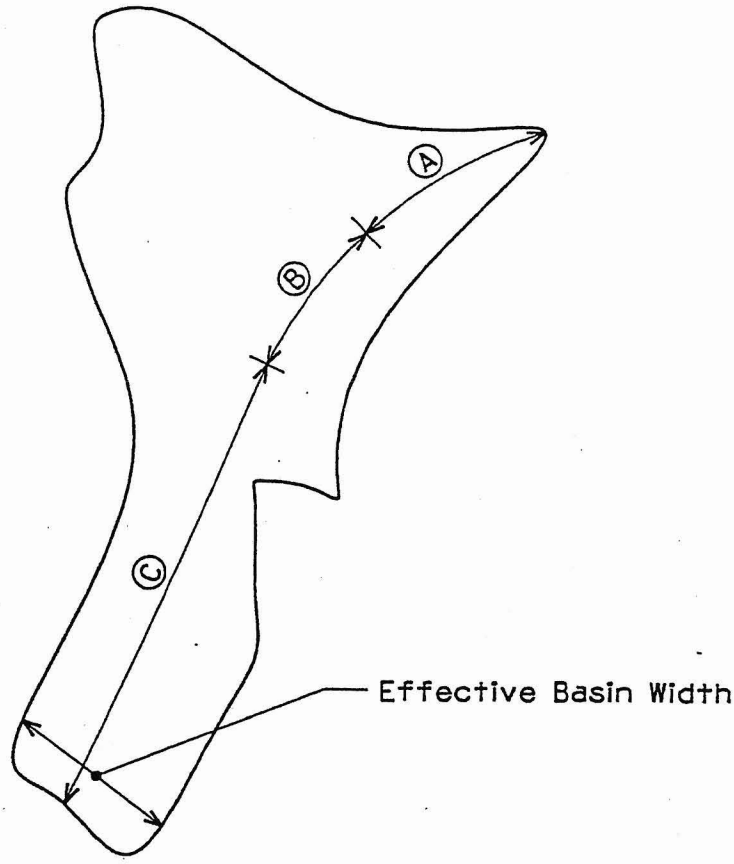
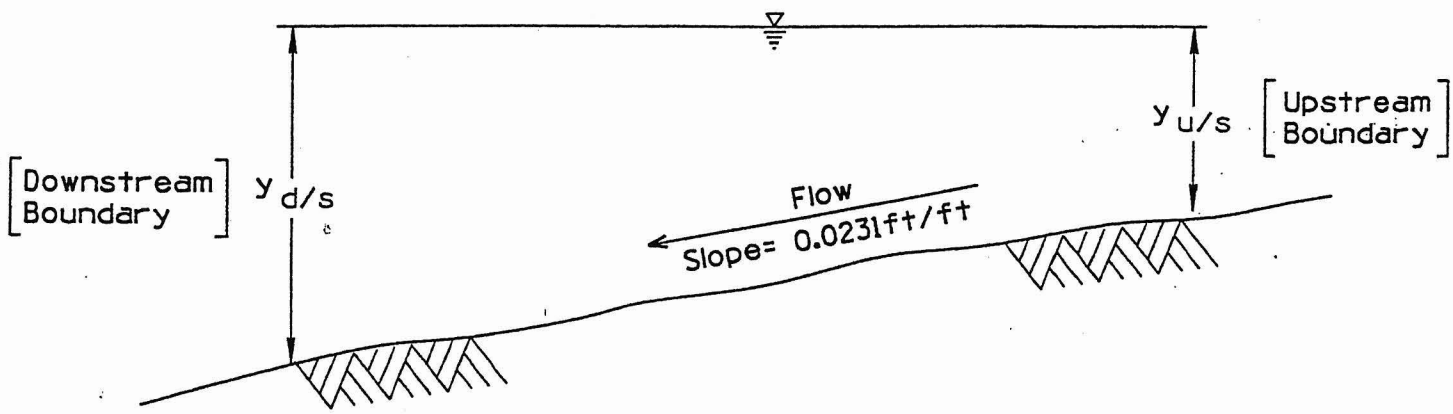



**FIGURE 1. PLAN VIEW OF SUBBASIN B1**




$y_{u/s}$ = Flow depth at the upstream end of the channel flow segment.

$y_{d/s}$ = Flow depth at the downstream end of the channel flow segment.

**FIGURE 2. CHANNEL FLOW SEGMENT OF SUBBASIN B1 (PROFILE)**

A new computational process was developed by DMJM+HARRIS to define the travel time along the channel flow segment. The key parameters in this process are the upstream and downstream boundary conditions, which are expressed in terms of the flow depth (see Figure 2). Once these flow depths are established, an average flow depth is computed for the channel flow segment. The associated flow velocity, computed using Manning's equation, is then used to compute the travel time through the channel segment. This algorithm, summarized in Figure 3, is repeated until the time of concentration converges. A step-by-step process to compute the time of concentration is outlined below.

**Step 1 – Upstream Boundary Condition**

- Compute the average velocity (V) along the shallow concentrated flow segment using the procedures outlined in TR-55 (Figure 3.1).
- Compute the travel time for shallow concentrated flow ($T_{shallow}$) using the procedures outlined in TR-55.
- Compute the associated flow depth using the Manning's equation. Assume a hydraulically wide channel (hydraulic radius is equal to the flow depth).
- Use this flow depth ($y_{u/s}$) as the upstream boundary condition for the channel flow segment.
- Compute the travel time for the sheet flow ($T_{sheet}$) using the procedures outlined in TR-55.
- Set i=1 (iteration counter for time of concentration computations).

**Step 2 – Downstream Boundary Condition**

- Assume an initial discharge (Q) at the downstream boundary of the subbasin or watershed.
- Compute the associated flow depth using the Manning's equation. Assume a hydraulically wide channel.
- Use this flow depth ($y_{d/s}$) as the downstream boundary condition of the channel flow segment.

**Step 3 – Average Channel Flow Parameters**

- Compute the average flow depth ($y_{avg}$) along the channel flow segment using the upstream and downstream boundary depths in Steps 1 and 2, respectively.
- Compute the average flow velocity ($V_{avg}$) using the Manning's equation.

**Step 4 – Travel Time-Channel**

- Compute the travel time ($T_{channel}$) along the channel flow segment using the following equation:

$$T_{channel} = \frac{L}{3600\, V_{avg}}$$

L = length of the channel flow segment, feet

**Step 5 – Time of Concentration**

- Compute the time of concentration for the subbasin;

$$Tci = T_{sheet} + T_{shallow} + T_{channel} \qquad i=1 \text{ to } N$$

Where, N is equal to the number of iterations required for the convergence criteria in Step 6.

- Compute the storage coefficient for the Clark Unit Hydrograph, R, using the guidelines in the FCDMC Hydrology Manual (1995).

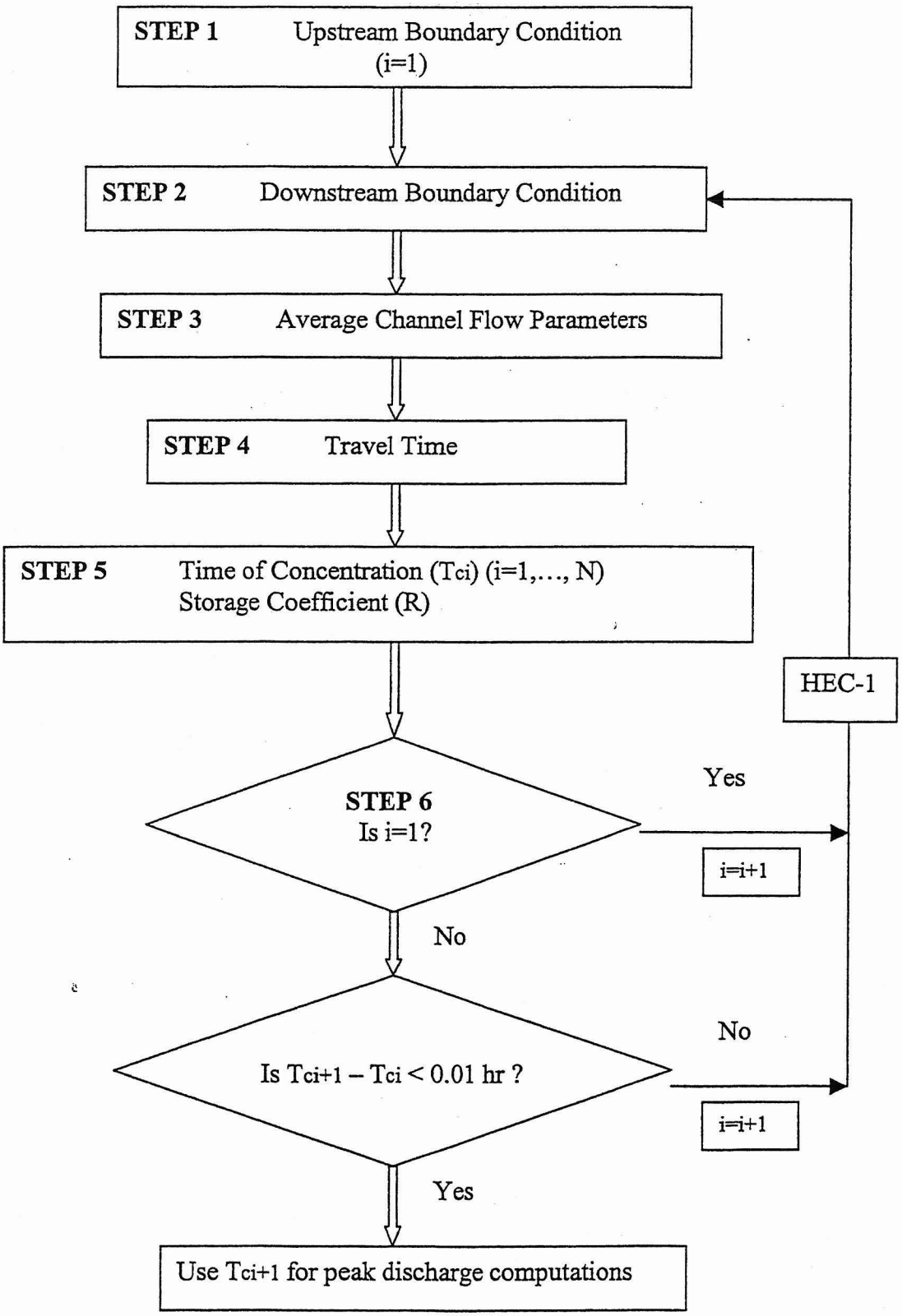



**FIGURE 3. TIME OF CONCENTRATION COMPUTATION ALGORITHM**

**Step 6 – Iterative Process for Tc convergence**

- If i=1 Compute the associated peak discharge using HEC-1 and go to Step 2. Set i = i + 1
- If i is greater than 1 check the following criteria:

  If (Tci+1) – (Tci) ≤ 0.01 hr.

  Set i = i + 1. Use Tci+1 and corresponding R in HEC-1.

  If (Tci+1) – (Tci) > 0.01 hr.

  Set i = i + 1. Repeat Steps 2-6 until Tc convergence.

  (Tci+1 = time of concentration computed at the i+1 iteration, hours)

Example calculations for this procedure are provided in Appendix A.

## RESULTS AND RECOMMENDATIONS

As documented in the DMJM+HARRIS draft hydrology report, the time of concentration variable has the greatest impact on the peak flow estimates. The major limitation of the FCDMC time of concentration methodology is that the relationship was expressed as a function of rainfall intensity. In an application such as the PMF analysis for the Spook Hill watershed, this methodology results in unrealistically low times of concentration.

The original design by the SCS used an empirical relationship in which the average velocity was expressed as a function of average channel slope. The time of concentration was computed by dividing the total subbasin length by this average velocity. The SCS empirical approach is simplified and conservatively defines the lumped physical parameters within the watershed.

The proposed method presented in this paper uses a more detailed approach to compute the time of concentration. The key parameters in this proposed methodology are:

- the upstream and downstream boundary conditions, and
- effective basin width at the downstream end of the channel flow segment.

The results of these three different methodologies for time of concentration and peak flow estimates for the PMF event are summarized in the following table. For rural subbasins the base Manning's roughness coefficient along the channel flow segment of the subbasins was adjusted for factors such as the irregularity, variation in channel cross section, obstructions, vegetation and meandering. For urban subbasins the base Manning's roughness coefficient was adjusted using the procedures and guidelines recommended in the FCDMC Hydraulics Manual.

**Summary of Results**

| Subbasin No.* | Time of Concentration (hr) | | | Peak Flow Rate (cfs) | | |
|---|---|---|---|---|---|---|
| | FCDMC | SCS | Proposed | FCDMC** | SCS*** | Proposed** |
| B1 | 0.314 | 1.190 | 1.980 | 41,849 | 15,675 | 10,523 |
| C1 | 0.249 | 0.830 | 0.960 | 29,594 | 9,124 | 12,970 |

* Subbasins B1 and C1 are labeled as 19 and 21 in the original design report by the SCS.
** Green-Ampt Infiltration and Clark Unit Hydrograph.
*** SCS methods for Infiltration and Unit Hydrograph.

Since the proposed methodology is based on the physical hydrologic and hydraulic parameters within the watershed, it results in the most realistic estimates of time of concentration. It is recommended that the proposed procedure presented in this white paper be used to define the inflow design flood for the contributing Spook Hill FRS watershed.

**REFERENCES**

Arizona Department of Transportation, "Highway Drainage Design Manual, Volume 1 – Hydrology," March 1993.

Ertec Western, Inc., "Phase I Inspection Report for Spook Hill Retarding Dam, I.D. No. AZ00175," August 1981.

Flood Control District of Maricopa County, "Drainage Design Manual for Maricopa County, Arizona, Volume I, Hydrology," 1995.

Flood Control District of Maricopa County, "Drainage Design Manual for Maricopa County, Arizona, Volume II, Hydraulics," 1996.

Papadakis, C. N., and Kazan, M. N., "Time of Concentration in Small, Rural Watersheds," Proceedings of the Engineering Hydrology Symposium, ASCE, Virginia, 1987.

Soil Conservation Service, "National Engineering Handbook, Section 4, Hydrology," August 1972.

Soil Conservation Service, "Hydrology-Buckhorn Mesa Watershed-Spook Hill Reservoir," (Evaluation of Preliminary Design Report), May 1975.

Soil Conservation Service, "Buckhorn-Mesa WPP, AZ, Spook Hill FRS, Final Design," December 1976.

Soil Conservation Service, "Urban Hydrology for Small Watersheds," Technical Release No. 55 (TR-55), 1986.

U.S. Army Corps of Engineers, "HEC-1 Flood Hydrograph Package User's Manual," Hydrologic Engineering Center, 1990.

U.S. Army Corps of Engineers, HEC-1 Computer Program, Version 4.1, 1998.

U.S. Geological Survey, " Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains," Water-Supply Paper 2339, 1989.

# APPENDIX A

# EXAMPLE CALCULATIONS

SCS Design

In the original design report by the Soil Conservation Service (NRCS), an empirical approach was used to compute the time of concentration (Tc). Tc was expressed as a function of average basin length and velocity.

$$T_c = L / V$$

Where:

$T_c$ = time of concentration, seconds
L = average drainage length, ft
V = average velocity, ft/s

An empirical relationship was established to express the average velocity as a function of average channel bottom slope as follows:

- If the average slope within the subbasin is greater than 0.02 ft/ft, a velocity of 6 ft/s was assumed.
- If the average slope within the subbasin is less than 0.02 ft/ft, a velocity of 4 ft/s was assumed.

Proposed Design

The numerical results for representative rural (subbasin B1) and urban (subbasin C1) subbasins are summarized in Tables 1-3. Following the results, a hand computation for subbasin B1 is provided.

The Manning's n values used in the channel flow segment are summarized in the table below. The following resources were used to identify the representative roughness values:

- Field reconnaissance completed on July 11, 2001 (see Appendix B);
- Aerial photo dated January 13, 2000,
- Open-Channel Hydraulics (Chow, 1959), and
- USGS 7.5 Minute Series topographic quadrangle map.

**Adjusted Manning's n Values**

| Subbasin No. | $n_b$ | $n_1$ | $n_2$ | $n_3$ | $n_4$ | m | n |
|---|---|---|---|---|---|---|---|
| B1 | 0.040 | 0.0025 | 0.000 | 0.004 | 0.005 | 1.0 | 0.052 |
| | | | | | | | |
| C1 | $n_b$ | $W_T$ (ft) | $W_o$ (ft) | $L_T$ (ft) | $L_O$ (ft) | | n |
| | 0.030 | 6,472 | 5,537 | 2,072 | 1,616 | | 0.034 |

For subbasin B1, the guidelines in the USGS Water-Supply Paper 2339 (1989) were used to adjust the base Manning's n as follows:

$$n = (nb + n1 + n2 + n3 + n4)\ m$$

Where:

nb = a base value of n for a straight, uniform, smooth channel in natural materials,
n1 = a correction factor for the effect of surface irregularities,
n2 = a value for variations in shape and size of the channel cross-section,
n3 = a value for obstructions,
n4 = a value for vegetation and flow conditions, and
m = a correction factor for meandering of the channel.

For subbasin C1, guidelines in the Flood Control District of Maricopa County (FCDMC) Hydraulics Manual were used to adjust the base Manning's n. In the urban setting the following equation is recommended for use:

$$n = n_b \left( 1.5 \frac{W_T}{\sum W_o} + \left( 1 - \frac{W_T}{\sum W_o} \right) \frac{\sum L_o}{L_T} - 0.5 \right)$$

Where:

$n_b$ = base Manning's n for the area between the buildings

$W_T$ = total width of the channel including the floodplains, ft

$W_o$ = clear width between buildings, measured perpendicular to flow, ft

$L_T$ = Total length of the channel, including buildings, ft

$L_o$ = individual length between buildings measured parallel to flow, ft

**Table 1. Time of Concentration for Subbasin B1**

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.90 | 34,873 | 0.0160 | 0.052 | 3,600 | 1.81 | 1.35 | 0.0231 | 5.32 | 22,475 | 1.17 | 0.42 | 1.60 | 1.086 |
| 2 | 0.90 | 12,631 | 0.0160 | 0.052 | 3,600 | 0.98 | 0.94 | 0.0231 | 4.17 | 22,475 | 1.50 | 0.42 | 1.92 | 1.331 |
| 3 | 0.90 | 10,762 | 0.0160 | 0.052 | 3,600 | 0.89 | 0.90 | 0.0231 | 4.04 | 22,475 | 1.55 | 0.42 | 1.97 | 1.369 |
| 4 | 0.90 | 10,523 | 0.0160 | 0.052 | 3,600 | 0.88 | 0.89 | 0.0231 | 4.02 | 22,475 | 1.55 | 0.42 | 1.98 | 1.374 |

**Table 2. Time of Concentration for Subbasin C1**

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.80 | 24,379 | 0.0163 | 0.034 | 6,250 | 0.81 | 0.80 | 0.0309 | 6.64 | 13,937 | 0.58 | 0.30 | 0.89 | 0.383 |
| 2 | 0.80 | 13,679 | 0.0163 | 0.034 | 6,250 | 0.57 | 0.68 | 0.0309 | 5.97 | 13,937 | 0.65 | 0.30 | 0.95 | 0.414 |
| 3 | 0.80 | 12,970 | 0.0163 | 0.034 | 6,250 | 0.55 | 0.68 | 0.0309 | 5.91 | 13,937 | 0.65 | 0.30 | 0.96 | 0.417 |

**Table 3. Sheet and Shallow Concentrated Flow Computations**

**Sheet Flow (Subbasin B1)**

| Surface Description | | Range |
|---|---|---|
| Manning's n | | 0.13 |
| Flow Length, L | ft | 300 |
| 2-yr 24-hr precip, p2* | in | 1.4 |
| Land Slope, s | ft/ft | 0.667 |
| Travel Time, Tsheet | hr | 0.13 |

$$T_{sheet} = \frac{0.007\,(nL)^{0.8}}{p_2^{0.5}\, s^{0.4}}$$

*Precipitation depth, p2
Latitude: 33 27 North, Longitude: 111 38 West
From NOAA Atlas, p2 = 1.4 in

**Sheet Flow (Subbasin C1)**

| Surface Description | | Range |
|---|---|---|
| Manning's n | | 0.13 |
| Flow Length, L | ft | 300 |
| 2-yr 24-hr precip, p2 | in | 1.4 |
| Land Slope, s | ft/ft | 0.500 |
| Travel Time, Tsheet | hr | 0.15 |

**Shallow Concentrated Flow (Subbasin B1)**

| Surface description | | Unpaved |
|---|---|---|
| Flow length, L | ft | 6,075 |
| Land slope, s* | ft/ft | 0.132 |
| Average velocity, V ** | ft/s | 5.75 |
| Travel Time, Tshallow | hr | 0.29 |
| Total Travel Time*** | hr | 0.42 |

$$T_{shallow} = \frac{L}{3600\,V}$$

* Average land slope along shallow concentrated flow segment
** Use TR-55
*** Sheet and Shallow Concentrated Flow

**Shallow Concentrated Flow (Subbasin C1)**

| Surface description | | Unpaved |
|---|---|---|
| Flow length, L | ft | 3,530 |
| Land slope, s | ft/ft | 0.153 |
| Average velocity, V | ft/s | 6.25 |
| Travel Time, Tshallow | hr | 0.16 |
| Total Travel Time | hr | 0.30 |

**Upstream Boundary (Flow Depth)**

| Velocity* (ft/s) | Bottom** Slope (ft/ft) | Manning's n | Flow*** Depth (ft) |
|---|---|---|---|
| 5.75 | 0.0430 | 0.05 | 0.90 |

* Average velocity along shallow concentrated flow
** Average bottom slope at the downstream end of the shallow concentrated flow
*** Flow Depth was computed using the Manning's equation

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 6.25 | 0.0597 | 0.05 | 0.80 |

| DMJM | PROJECT: RED MOUNTAIN FREEWAY (POWER RD – UNIVERSITY DR.) | JOB NO. | SHEET 1 of 5 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 07/25/01 |
| SUBJECT: Time of Concentration Computations | | CHECKED BY JRM | DATE 7/29/01 |

⇒ STEP 1

UPSTREAM BOUNDARY — Compute $y_{u/s}$ for Subbasin B1

Use the procedures and guidelines in TR-55

Shallow Concentrated Flow

Surface description: Unpaved

Flow length, L : 6,075 ft (use USGS quad map)

Land slope, s : 0.132 ft/ft (use USGS quad map)

Average velocity, V : 5.75 ft/s (TR-55 Figure 3.1) ✓

Travel time, $T_{shallow}$ : 0.29 hr.

$$T_{shallow} = \frac{L}{3600(V)} = \frac{6,075}{3600(5.75)} = 0.29 \text{ hr.}$$ ✓

Use Manning's equation to compute $y_{u/s}$

$$y_{u/s} = \left(\frac{V\,n}{1.486\,s^{1/2}}\right)^{3/2}$$

Where:

s = 0.043 ft/ft (use USGS quad map)

(slope is measured in the vicinity of the downstream end of the shallow concentrated flow segment)

$$y_{u/s} = \left(\frac{5.75\,(0.05)}{1.486\,(0.043)^{1/2}}\right)^{3/2} = 0.90 \text{ ft.}$$ ✓

| DMJM | PROJECT: | JOB NO. | SHEET 2 of 5 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 07/25/01 |
| SUBJECT: | | CHECKED BY JEM | DATE 7/29/01 |

Sheet flow

Surface Description : Range

Manning's n : 0.13

Flow length, L : 300 ft

2-year 24-hour rainfall, $P_2$ : 1.4 in

Land slope, s : 0.667 ft/ft (use USGS quad map)

Travel time, $T_{sheet}$ : 0.13 hr.

$$T_{sheet} = \frac{0.007(nL)^{0.8}}{P_2^{0.5}\, s^{0.4}} = \frac{0.007(0.13 * 300)^{0.8}}{(1.4)^{0.5}(0.667)^{0.4}}$$

$$= 0.13 \text{ hr.}$$

Total travel time = $T_{sheet} + T_{shallow}$

$= 0.13 + 0.29$

$= 0.42$ hr.

| DMJM | PROJECT: | JOB NO. | SHEET 3 of 5 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 07/25/01 |
| SUBJECT: | | CHECKED BY JRM | DATE 7/29/07 |

⇒ STEP 2

DOWN STREAM BOUNDARY Compute $y_{dls}$ for Subbasin B1

Peak Discharge, Q = 34,873 cfs (use Technical Report No. 1, January 2001)

Effective basin width, b = 3,600 ft (measured at the downstream end of Subbasin B1)

Manning's n : 0.052 (see Table 7)

Land slope, s : 0.016 ft/ft (use USGS quad map) (measured at the downstream end of the channel flow segment)

$$y_{dls} = \left(\frac{Q\,n}{1.486\,b\,s^{1/2}}\right)^{3/5} = \left(\frac{34{,}873 * 0.052}{1.486\,(3{,}600)(0.016)^{1/2}}\right)^{3/5}$$

$$= 1.81 \text{ ft.}$$

| DMJM | PROJECT: | JOB NO. | SHEET 4 of 5 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 07/25/01 |
| SUBJECT: | | CHECKED BY JRM | DATE 7/29/01 |

⇒ STEP 3

AVERAGE CHANNEL FLOW PARAMETERS

Average depth, $y_{avg} = \left(\frac{y_{u/s} + y_{d/s}}{2}\right) = \left(\frac{0.90 + 1.81}{2}\right) = 1.36$ ft.

Average slope, $s = 0.0231$ ft/ft (use USGS quad map)
(average slope measured along the channel flow segment)

Manning's $n = 0.052$

Average velocity, $V_c = 5.33$ ft/s

$$V_{avg} = \frac{1.486}{n} y_{avg}^{2/3} s^{1/2}$$

$$= \frac{1.486}{0.052} (1.36)^{2/3} (0.0231)^{1/2} = 5.33 \text{ ft/s.}$$

Average length, $L = 22,475$ (use USGS quad map)

⇒ STEP 4

TRAVEL TIME

Travel time along channel flow, $T_{channel}$ = 1.17 hr.

$$T_{channel} = \frac{L}{3600\,(V_c)} = \frac{22,475}{3600\,(5.33)} = 1.17 \text{ hr.}$$

⇒ STEP 5

TIME OF CONCENTRATION

Time of Concentration = $T_{sheet} + T_{shallow} + T_{channel}$

$= 0.13 + 0.29 + 1.17$

$= 1.59$ hr.

Storage Coefficient, R = 1.086 hr.

$$R = 0.37\, T_c^{1.11}\, A^{-0.57}\, L^{0.80}$$

Where:

A = drainage area ($mi^2$)

L = Total length along the sheet, shallow and channel flow segments of the subbasin, mi

$$R = 0.37\,(1.59)^{1.11}\,(4.089)^{-0.57}\,(28,850/5280)^{0.80}$$

$= 1.079$ hr.

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
* RUN DATE   29JUL01  TIME  17:14:03   *
*                                      *
****************************************
```

```
****************************************
*                                      *
*   U.S. ARMY CORPS OF ENGINEERS       *
*   HYDROLOGIC ENGINEERING CENTER      *
*         609 SECOND STREET            *
*      DAVIS, CALIFORNIA 95616         *
*          (916) 756-1104              *
*                                      *
****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X       XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: HEC1-C1.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS THE EXISTING CONDITION OF SUBBASIN B1
  7           ID   BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
  8           ID   MANUAL.
  9           ID   DRAINAGE AREA IS APPROXIMATELY 2.537 SQ. MI.
 10           ID
 11           ID   HEC-1 MODEL PARAMETERS:
 12           ID     DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 13           ID            WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 14           ID            SUBBASIN LENGTH, SLOPE AND AREA.
 15           ID     HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
 16           ID     PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION.
 17           ID            COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 18           ID     RAINFALL DURATION: 6 HRS
 19           ID     RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.
 20           ID     LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 21           ID            HYDROLOGY MANUAL (1995).
 22           ID     RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS
 23           ID            RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).
 24           IT       2                    200
 25           IO       3

 26           KK    S-C1
 27           KM    Runoff from Sub-basin C1
 28           BA   2.537
 29           IN      15
 30           PB   12.76
 31           KM    HMR 49 (1977) was used to distribute the local PMP
 32           PC   .000    .008    .016    .023    .031    .041    .051    .061    .070    .098
 33           PC   .125    .152    .180    .648    .789    .859    .914    .928    .941    .955
 34           PC   .969    .977    .984    .992   1.000    .000    .000    .000    .000    .000
 35           LG   .310    .260   4.350    .460  15.000
 36           UC   0.95   0.414
 37           UA     0     4.5    12.6    23.2    35.8      50    64.2    76.8    87.4    95.5
 38           UA    100
 39           ZZ
```

```
****************************************
*                                      *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
* RUN DATE   29JUL01  TIME  17:14:03   *
*                                      *
****************************************
```

```
****************************************
*                                      *
*   U.S. ARMY CORPS OF ENGINEERS       *
*   HYDROLOGIC ENGINEERING CENTER      *
*         609 SECOND STREET            *
*      DAVIS, CALIFORNIA 95616         *
*          (916) 756-1104              *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: HEC1-C1.DAT

THIS MODEL REPRESENTS THE EXISTING CONDITION OF SUBBASIN B1
BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
MANUAL.
DRAINAGE AREA IS APPROXIMATELY 2.537 SQ. MI.

HEC-1 MODEL PARAMETERS:

DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE SUBBASIN LENGTH, SLOPE AND AREA.

HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)

PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION. COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.

RAINFALL DURATION: 6 HRS

RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.

LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

```
25 IO        OUTPUT CONTROL VARIABLES
                  IPRNT          3  PRINT CONTROL
                  IPLOT          0  PLOT CONTROL
                  QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT        HYDROGRAPH TIME DATA
                   NMIN          2  MINUTES IN COMPUTATION INTERVAL
                  IDATE      1   0  STARTING DATE
                  ITIME       0000  STARTING TIME
                     NQ       2000  NUMBER OF HYDROGRAPH ORDINATES
                 NDDATE      3   0  ENDING DATE
                 NDTIME       1838  ENDING TIME
                  ICENT         19  CENTURY MARK

            COMPUTATION INTERVAL     .03 HOURS
                 TOTAL TIME BASE   66.63 HOURS

      ENGLISH UNITS
          DRAINAGE AREA          SQUARE MILES
          PRECIPITATION DEPTH    INCHES
          LENGTH, ELEVATION      FEET
          FLOW                   CUBIC FEET PER SECOND
```

```
STORAGE VOLUME        ACRE-FEET
SURFACE AREA          ACRES
TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 26 KK    *     S-C1   *
          *            *
          **************
                         Runoff from Sub-basin C1
                         HMR 49 (1977) was used to distribute the local PMP

 29 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          15  TIME INTERVAL IN MINUTES
                     JXDATE      1    0  STARTING DATE
                     JXTIME           0  STARTING TIME

             SUBBASIN RUNOFF DATA

 28 BA          SUBBASIN CHARACTERISTICS
                      TAREA        2.54  SUBBASIN AREA

                PRECIPITATION DATA

 31 PB                STORM       12.76  BASIN TOTAL PRECIPITATION

 31 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

 35 LG          GREEN AND AMPT LOSS RATE
                     STRTL        .31  STARTING LOSS
                       DTH        .26  MOISTURE DEFICIT
                      PSIF       4.35  WETTING FRONT SUCTION
                     XKSAT        .46  HYDRAULIC CONDUCTIVITY
                     RTIMP      15.00  PERCENT IMPERVIOUS AREA

 36 UC          CLARK UNITGRAPH
                        TC        .95  TIME OF CONCENTRATION
```

R .41 STORAGE COEFFICIENT

37 UA ACCUMULATED-AREA VS. TIME, 11 ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .0 | 4.5 | 12.6 | 23.2 | 35.8 | 50.0 | 64.2 | 76.8 | 87.4 | 95.5 |
| 100.0 | | | | | | | | | |

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= .95 HR, R= .41 HR

SNYDER TP= .77 HR, CP= .77

UNIT HYDROGRAPH

82 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30. | 88. | 145. | 221. | 312. | 401. | 500. | 602. | 703. | 809. |
| 915. | 1018. | 1125. | 1227. | 1322. | 1409. | 1489. | 1554. | 1603. | 1646. |
| 1673. | 1684. | 1692. | 1683. | 1660. | 1632. | 1581. | 1519. | 1446. | 1349. |
| 1245. | 1148. | 1059. | 977. | 902. | 832. | 768. | 708. | 653. | 603. |
| 556. | 513. | 473. | 437. | 403. | 372. | 343. | 316. | 292. | 269. |
| 249. | 229. | 212. | 195. | 180. | 166. | 153. | 141. | 130. | 120. |
| 111. | 102. | 95. | 87. | 80. | 74. | 68. | 63. | 58. | 54. |
| 50. | 46. | 42. | 39. | 36. | 33. | 31. | 28. | 26. | 24. |
| 22. | 20. | | | | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-C1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.10, TOTAL EXCESS = 9.66

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 66.63-HR |
|---|---|---|---|---|---|---|
| 12970. | 3.93 | (CFS) | 2617. | 656. | 236. | 236. |
| | | (INCHES) | 9.591 | 9.612 | 9.612 | 9.612 |
| | | (AC-FT) | 1298. | 1301. | 1301. | 1301. |

CUMULATIVE AREA = 2.54 SQ MI

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

| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR | 24-HOUR | 72-HOUR | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|---|---|---|---|---|---|---|---|---|---|
| HYDROGRAPH AT | S-C1 | 12970. | 3.93 | 2617. | 656. | 236. | 2.54 | | |

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

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
* RUN DATE   29JUL01  TIME  17:15:06   *
*                                      *
****************************************
```

```
****************************************
*                                      *
*   U.S. ARMY CORPS OF ENGINEERS       *
*   HYDROLOGIC ENGINEERING CENTER      *
*         609 SECOND STREET            *
*      DAVIS, CALIFORNIA 95616         *
*         (916) 756-1104               *
*                                      *
****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X       X     X        XX
X     X  X       X              X
XXXXXXX  XXXX    X       XXXXX  X
X     X  X       X              X
X     X  X       X     X        X
X     X  XXXXXXX   XXXXX        XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: HEC1-B1.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS THE EXISTING CONDITION OF SUBBASIN B1
  7           ID   BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
  8           ID   MANUAL.
  9           ID   DRAINAGE AREA IS APPROXIMATELY 4.089 SQ. MI.
 10           ID
 11           ID   HEC-1 MODEL PARAMETERS:
 12           ID     DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 13           ID             WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 14           ID             SUBBASIN LENGTH, SLOPE AND AREA.
 15           ID     HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
 16           ID     PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION.
 17           ID             COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 18           ID     RAINFALL DURATION: 6 HRS
 19           ID     RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.
 20           ID     LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 21           ID             HYDROLOGY MANUAL (1995).
 22           ID     RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS
 23           ID             RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).
 24           IT       2                    200
 25           IO       3

 26           KK    S-B1
 27           KM    Runoff from Sub-basin B1
 28           BA   4.089
 29           IN      15
 30           PB   12.76
 31           KM    HMR 49 (1977) was used to distribute the local PMP
 32           PC    .000    .008    .016    .023    .031    .041    .051    .061    .070    .098
 33           PC    .125    .152    .180    .648    .789    .859    .914    .928    .941    .955
 34           PC    .969    .977    .984    .992   1.000    .000    .000    .000    .000    .000
 35           LG    .290    .250   4.450    .410  11.000
 36           UC    1.97   1.369
 37           UA      0     3.0     5.0     8.0    12.0      20    43.0    75.0    90.0    96.0
 38           UA     100
 39           ZZ
```

```
****************************************
*                                      *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
* RUN DATE   29JUL01  TIME  17:15:06   *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*          (916) 756-1104              *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: HEC1-B1.DAT

THIS MODEL REPRESENTS THE EXISTING CONDITION OF SUBBASIN B1
BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
MANUAL.
DRAINAGE AREA IS APPROXIMATELY 4.089 SQ. MI.

HEC-1 MODEL PARAMETERS:

DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
SUBBASIN LENGTH, SLOPE AND AREA.

HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)

PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION.
COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.

RAINFALL DURATION: 6 HRS

RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.

LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
HYDROLOGY MANUAL (1995).

RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS
RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

```
25 IO        OUTPUT CONTROL VARIABLES
                  IPRNT          3  PRINT CONTROL
                  IPLOT          0  PLOT CONTROL
                  QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT        HYDROGRAPH TIME DATA
                   NMIN          2  MINUTES IN COMPUTATION INTERVAL
                  IDATE      1   0  STARTING DATE
                  ITIME       0000  STARTING TIME
                     NQ       2000  NUMBER OF HYDROGRAPH ORDINATES
                 NDDATE      3   0  ENDING DATE
                 NDTIME       1838  ENDING TIME
                  ICENT         19  CENTURY MARK

            COMPUTATION INTERVAL     .03 HOURS
                 TOTAL TIME BASE   66.63 HOURS

      ENGLISH UNITS
          DRAINAGE AREA          SQUARE MILES
          PRECIPITATION DEPTH    INCHES
          LENGTH, ELEVATION      FEET
          FLOW                   CUBIC FEET PER SECOND
```

```
            STORAGE VOLUME        ACRE-FEET
            SURFACE AREA          ACRES
            TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 26 KK    *      S-B1  *
          *            *
          **************
                         Runoff from Sub-basin B1
                         HMR 49 (1977) was used to distribute the local PMP

 29 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          15  TIME INTERVAL IN MINUTES
                     JXDATE      1    0  STARTING DATE
                     JXTIME           0  STARTING TIME

            SUBBASIN RUNOFF DATA

 28 BA          SUBBASIN CHARACTERISTICS
                      TAREA        4.09  SUBBASIN AREA

                PRECIPITATION DATA

 31 PB                STORM       12.76  BASIN TOTAL PRECIPITATION

 31 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

 35 LG          GREEN AND AMPT LOSS RATE
                     STRTL         .29  STARTING LOSS
                       DTH         .25  MOISTURE DEFICIT
                      PSIF        4.45  WETTING FRONT SUCTION
                     XKSAT         .41  HYDRAULIC CONDUCTIVITY
                     RTIMP       11.00  PERCENT IMPERVIOUS AREA

 36 UC          CLARK UNITGRAPH
                        TC        1.97  TIME OF CONCENTRATION
```

R 1.37 STORAGE COEFFICIENT

37 UA ACCUMULATED-AREA VS. TIME, 11 ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .0 | 3.0 | 5.0 | 8.0 | 12.0 | 20.0 | 43.0 | 75.0 | 90.0 | 96.0 |
| 100.0 | | | | | | | | | |

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.97 HR, R= 1.37 HR

SNYDER TP= 1.65 HR, CP= .76

UNIT HYDROGRAPH

255 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5. | 14. | 24. | 33. | 42. | 50. | 57. | 62. | 67. | 72. |
| 76. | 81. | 88. | 95. | 103. | 110. | 117. | 124. | 133. | 143. |
| 152. | 161. | 170. | 181. | 199. | 220. | 240. | 260. | 280. | 310. |
| 363. | 428. | 492. | 554. | 615. | 682. | 762. | 847. | 930. | 1011. |
| 1089. | 1149. | 1180. | 1200. | 1219. | 1238. | 1257. | 1265. | 1258. | 1247. |
| 1236. | 1226. | 1215. | 1203. | 1187. | 1172. | 1156. | 1142. | 1127. | 1107. |
| 1081. | 1055. | 1030. | 1005. | 981. | 957. | 934. | 912. | 890. | 868. |
| 847. | 827. | 807. | 788. | 769. | 750. | 732. | 715. | 697. | 681. |
| 664. | 648. | 633. | 617. | 603. | 588. | 574. | 560. | 547. | 534. |
| 521. | 508. | 496. | 484. | 472. | 461. | 450. | 439. | 429. | 418. |
| 408. | 398. | 389. | 379. | 370. | 361. | 353. | 344. | 336. | 328. |
| 320. | 312. | 305. | 297. | 290. | 283. | 276. | 270. | 263. | 257. |
| 251. | 245. | 239. | 233. | 228. | 222. | 217. | 211. | 206. | 201. |
| 197. | 192. | 187. | 183. | 178. | 174. | 170. | 166. | 162. | 158. |
| 154. | 150. | 147. | 143. | 140. | 136. | 133. | 130. | 127. | 124. |
| 121. | 118. | 115. | 112. | 110. | 107. | 104. | 102. | 99. | 97. |
| 95. | 92. | 90. | 88. | 86. | 84. | 82. | 80. | 78. | 76. |
| 74. | 72. | 71. | 69. | 67. | 66. | 64. | 63. | 61. | 60. |
| 58. | 57. | 55. | 54. | 53. | 52. | 50. | 49. | 48. | 47. |
| 46. | 45. | 43. | 42. | 41. | 40. | 39. | 38. | 38. | 37. |
| 36. | 35. | 34. | 33. | 32. | 32. | 31. | 30. | 29. | 29. |
| 28. | 27. | 27. | 26. | 25. | 25. | 24. | 24. | 23. | 23. |
| 22. | 21. | 21. | 20. | 20. | 19. | 19. | 19. | 18. | 18. |
| 17. | 17. | 16. | 16. | 16. | 15. | 15. | 15. | 14. | 14. |
| 13. | 13. | 13. | 13. | 12. | 12. | 12. | 11. | 11. | 11. |
| 11. | 10. | 10. | 10. | 10. | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-B1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.04, TOTAL EXCESS = 9.72

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 66.63-HR |
|---|---|---|---|---|---|---|
| 10523. | 4.93 | (CFS) | 4109. | 1063. | 383. | 383. |
| | | (INCHES) | 9.343 | 9.672 | 9.672 | 9.672 |
| | | (AC-FT) | 2038. | 2109. | 2109. | 2109. |

CUMULATIVE AREA = 4.09 SQ MI

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

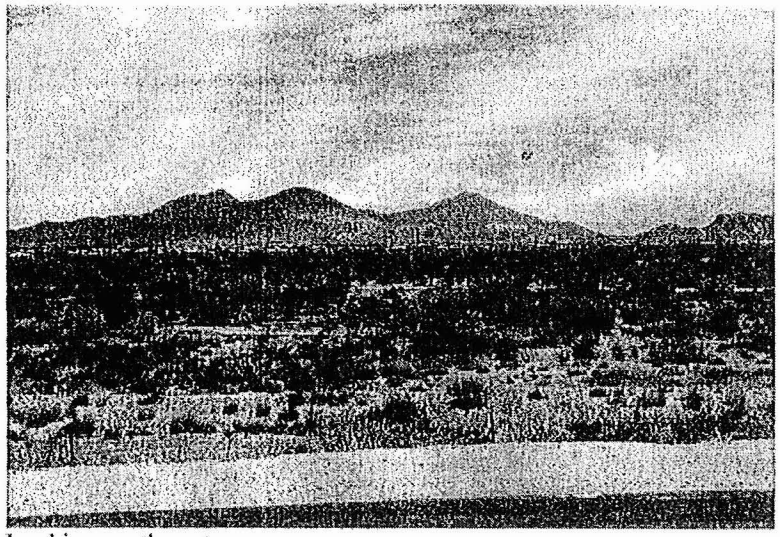
| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR | 24-HOUR | 72-HOUR | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|---|---|---|---|---|---|---|---|---|---|
| HYDROGRAPH AT | S-B1 | 10523. | 4.93 | 4109. | 1063. | 383. | 4.09 | | |

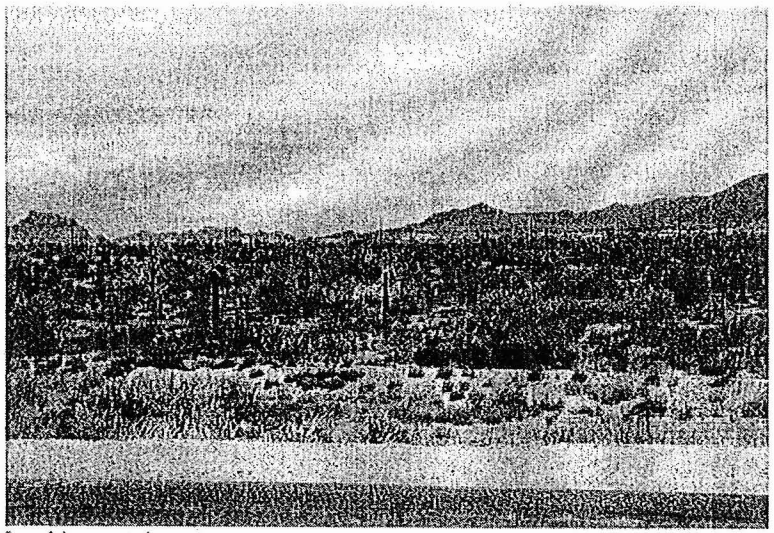
*** NORMAL END OF HEC-1 ***

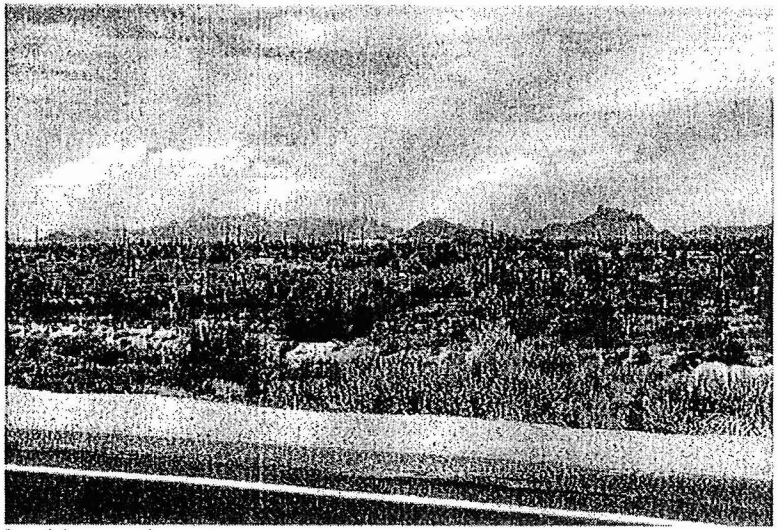
# APPENDIX B

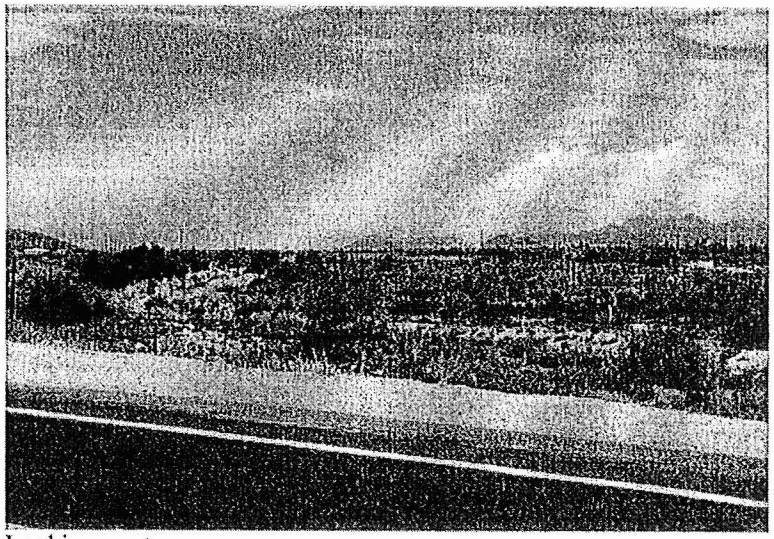
# FIELD RECONNAISSANCE

**SUBBASIN B1 Downstream end of the Channel Flow Segment**
**(pictures taken from the intersection of Brown Rd and Hawes Rd)**

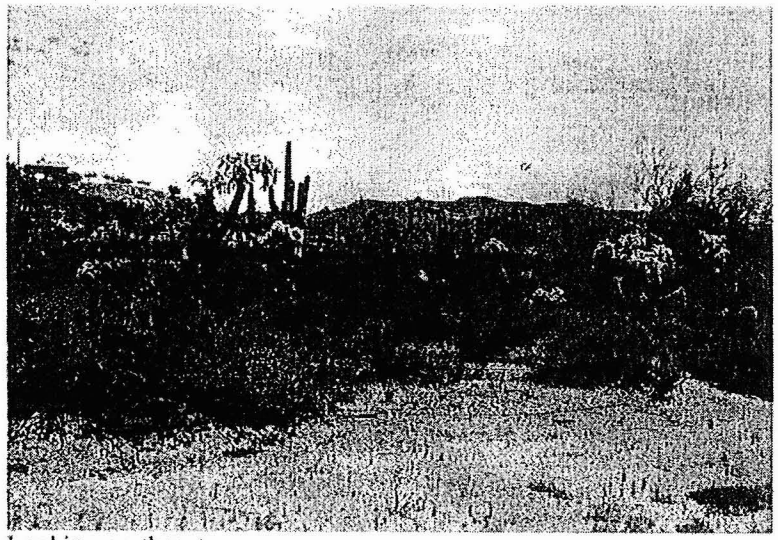

Looking northwest

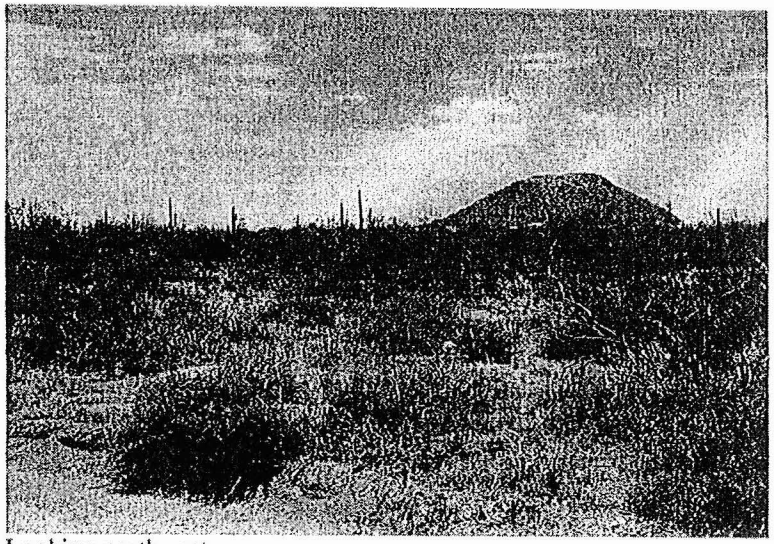

Looking northwest

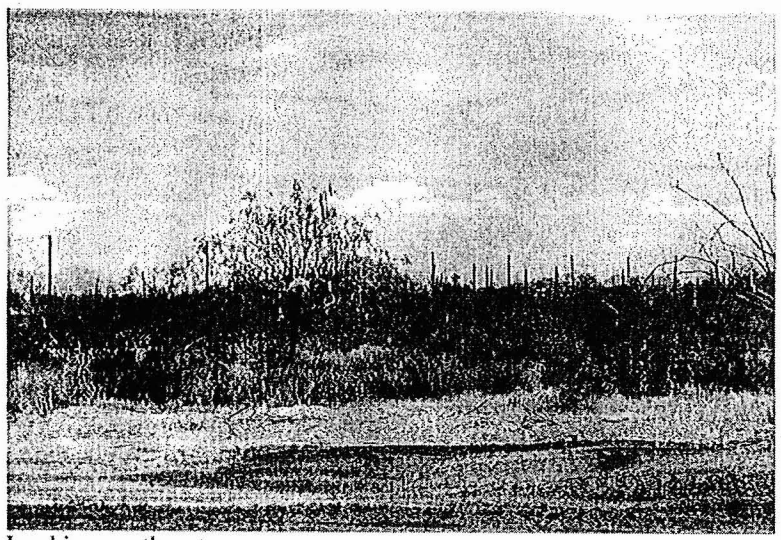

Looking northwest

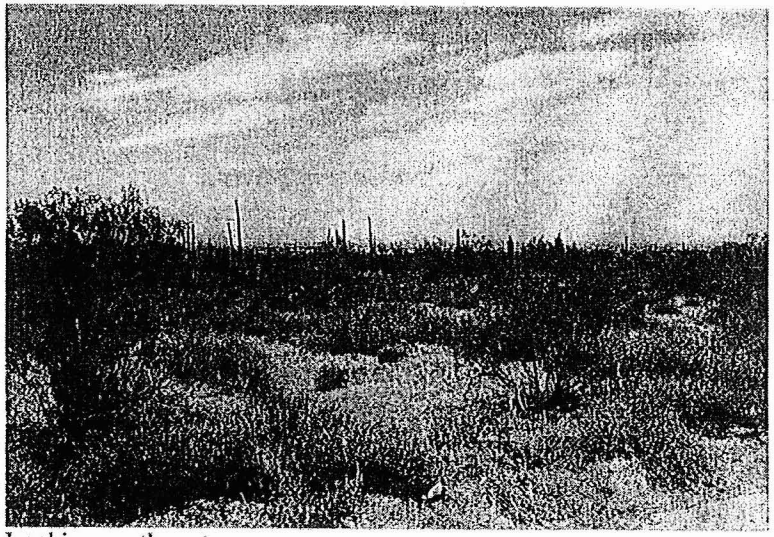

Looking west

**SUBBASIN B1 Channel Flow Segment**
**(pictures taken from approximately 0.25 mi northwest of McDowell Rd and Ellsworth Rd intersection)**

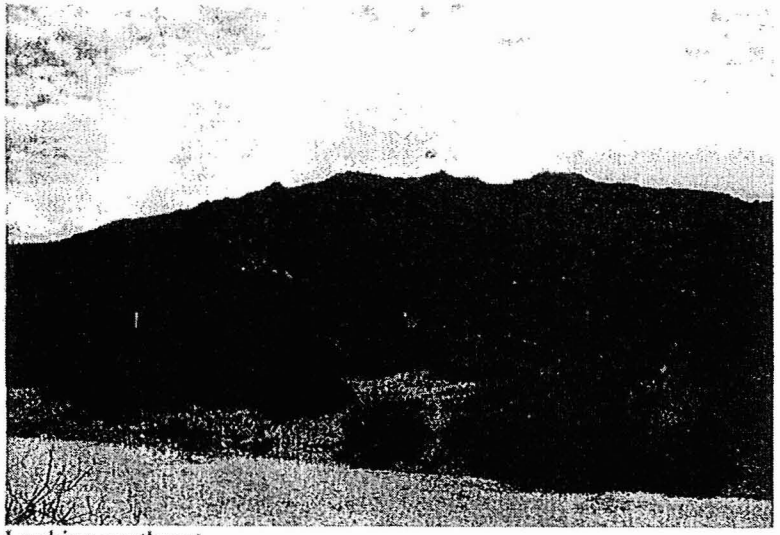

Looking northeast

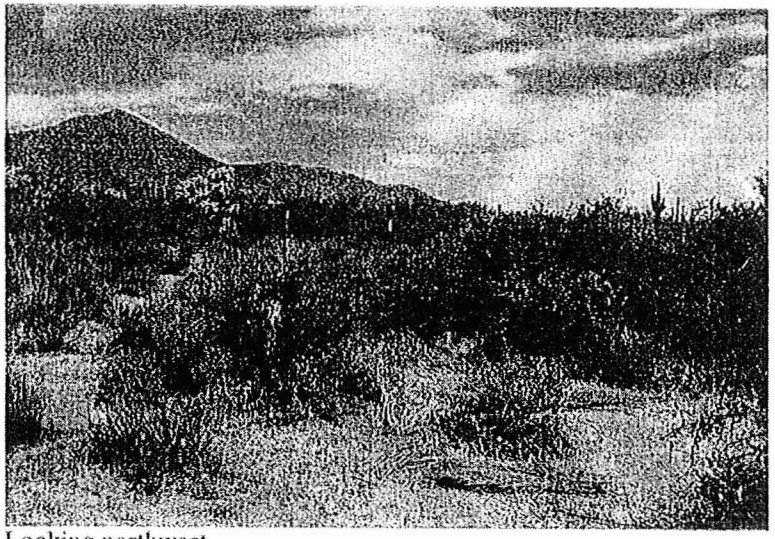

Looking northwest

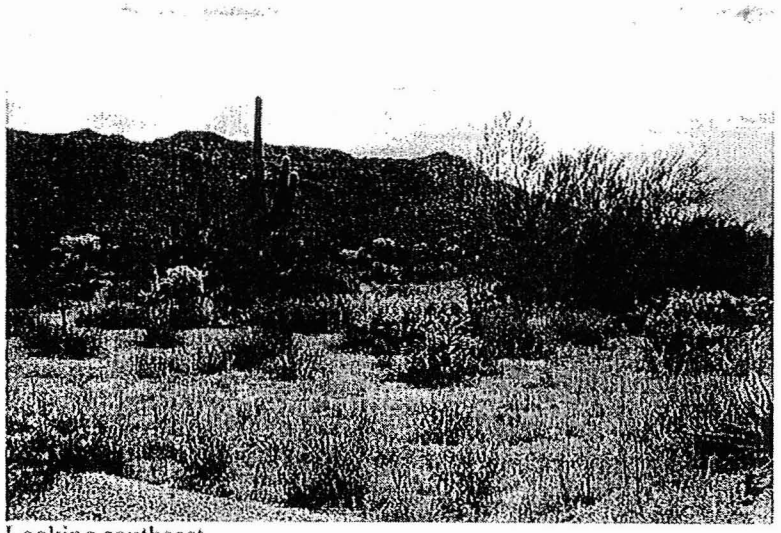

Looking southeast

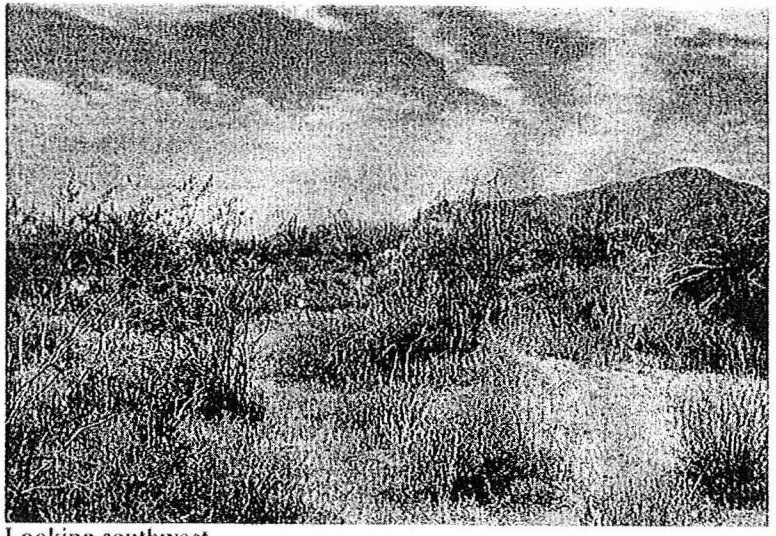

Looking southwest

**SUBBASIN B1 Downstream end of the Shallow Concentrated Flow Segment**
**(pictures taken from approximately 0.75 mi north-east of Thomas Rd and Ellsworth Rd)**

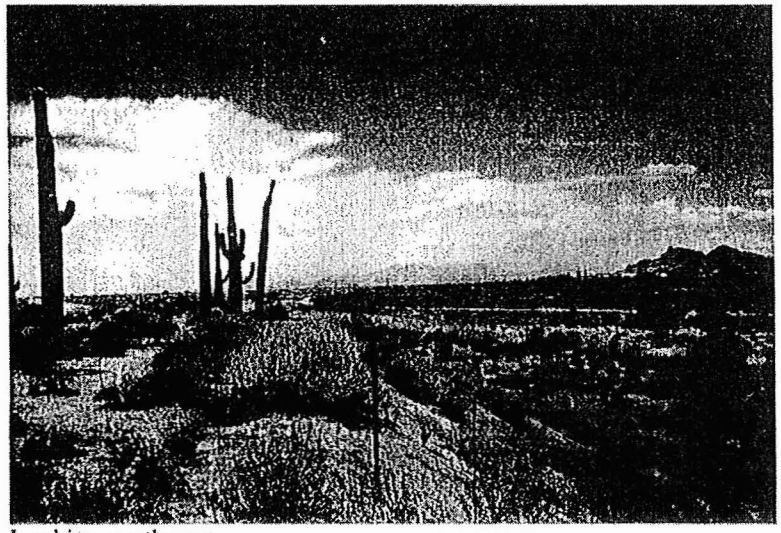

Looking northeast


Looking northwest

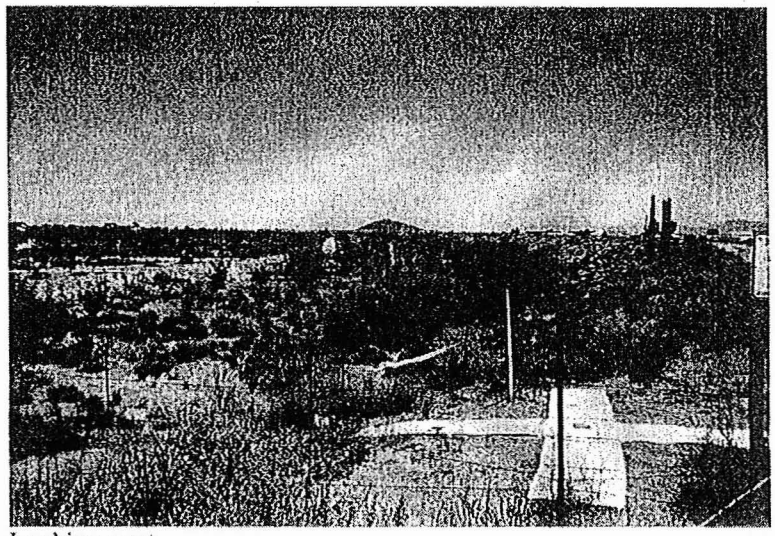

Looking southeast


Looking southwest

**SUBBASIN C1 Downstream end of the Channel Flow Segment**
**(pictures taken from approximately 0.25 mi east of McDowell Rd and Power Rd intersection)**

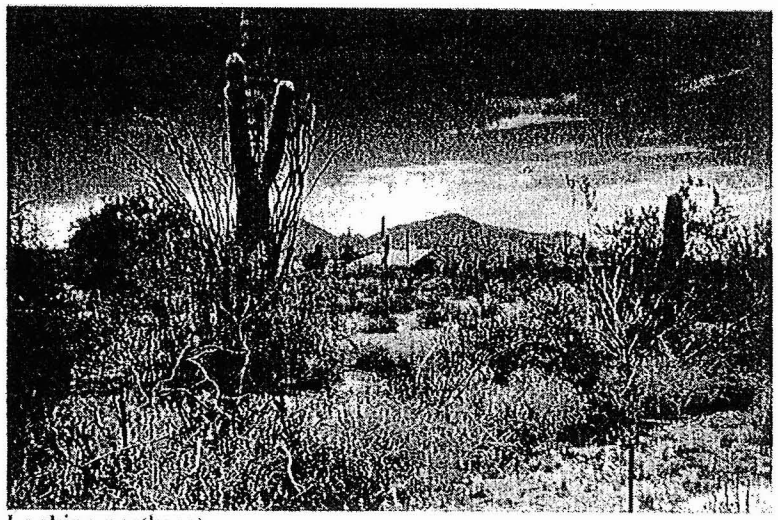


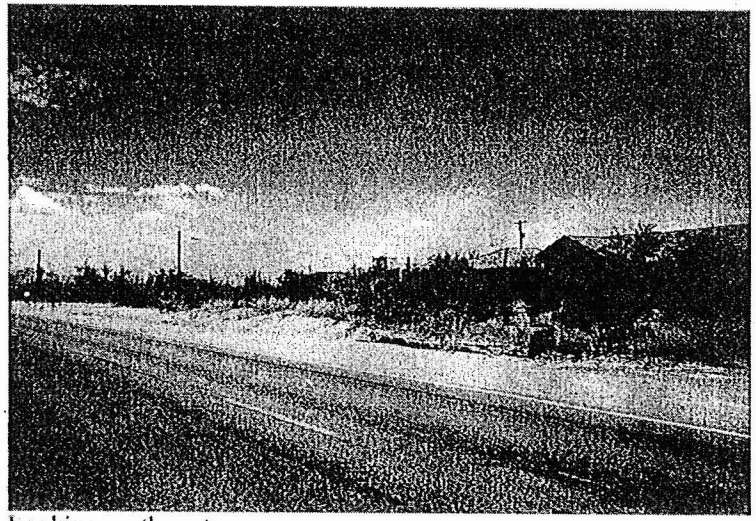
Looking northwest

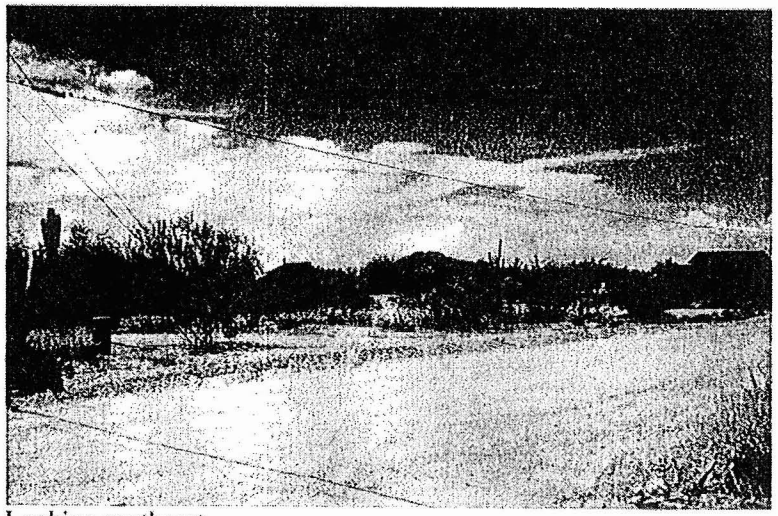


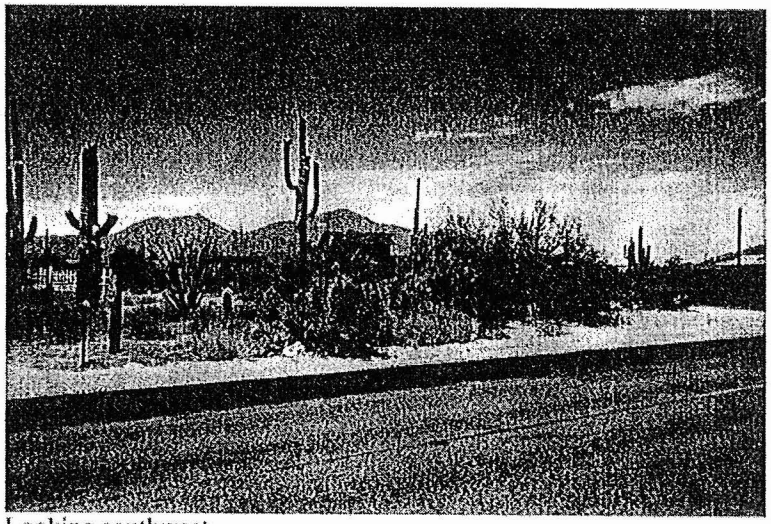
Looking west

**SUBBASIN C1 Channel Flow Segment**
**(pictures taken from approximately 0.50 mi east of McDowell Rd and Sossaman Rd intersection)**

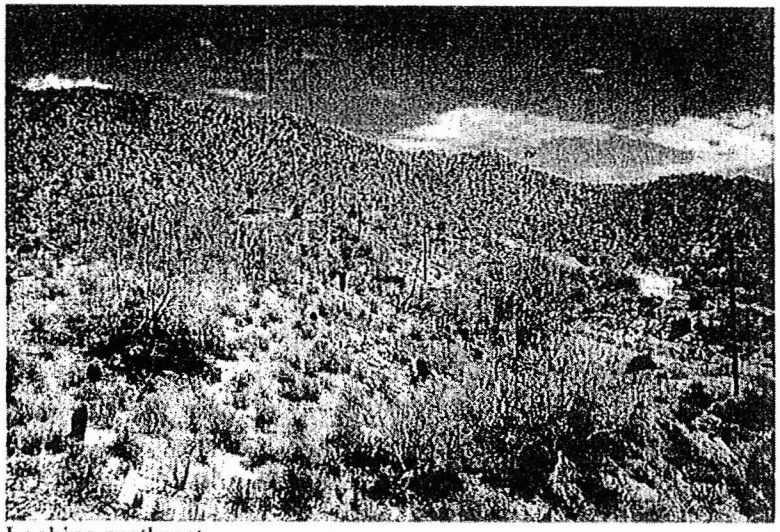

Looking northeast

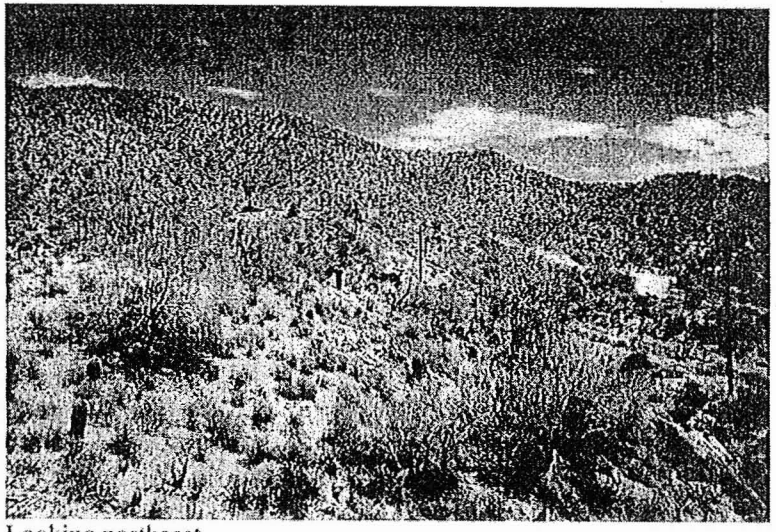

Looking northwest

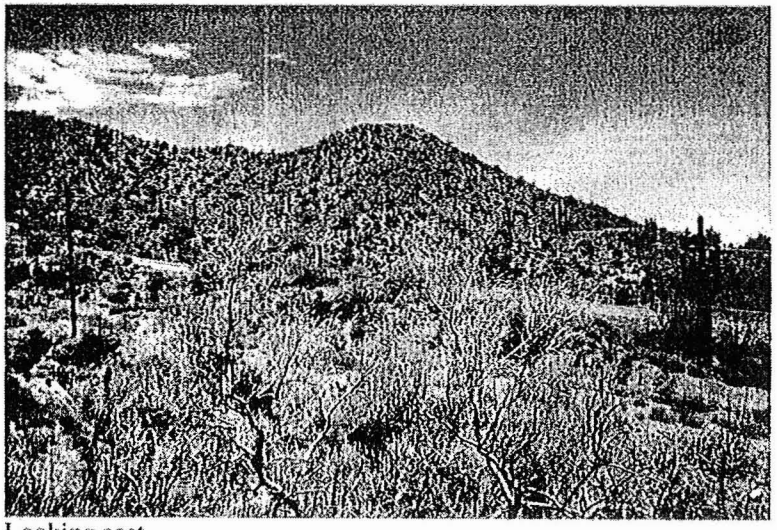

Looking southeast

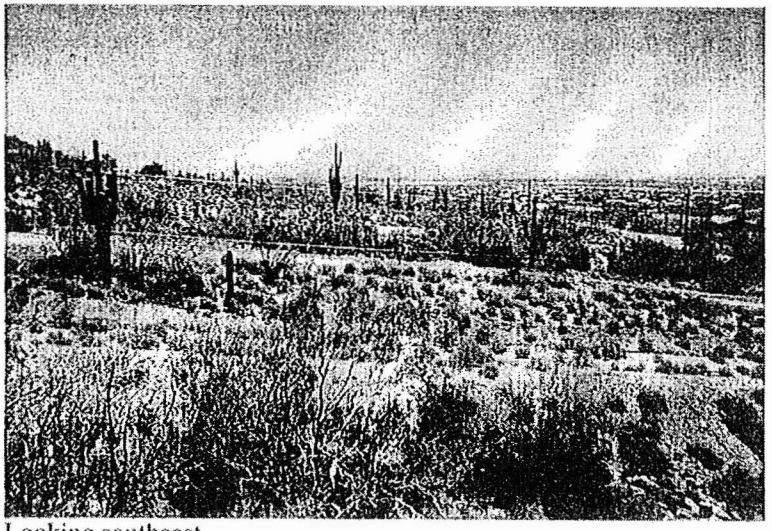

Looking southwest

**SUBBASIN C1 Downstream end of the Shallow Concentrated Flow Segment**
**(pictures taken from approximately 0.25 mi northeast of Thomas Rd and Hawes Rd intersection)**


Looking northeast


Looking northeast


Looking east


Looking southeast

# Appendix D2

## Spook Hill Floodwater Retarding Structure (FRS)
## Emergency Spillway Stage-Discharge Curve

# SPOOK HILL FLOODWATER RETARDING STRUCTURE (FRS) EMERGENCY SPILLWAY STAGE-DISCHARGE CURVE

**ABSTRACT:** A numerical procedure is presented for computing the emergency spillway stage-discharge relationship at the downstream end of the Spook Hill Floodwater Retarding Structure (FRS). The procedures and guidelines presented in the Soil Conservation Service (now the Natural Resource Conservation Service, NRCS) Technical Release 39 (TR-39) were used in the computations. A numerical example is provided.

## INTRODUCTION

The purpose of this paper is to define the procedures and guidelines that will be used to compute the emergency spillway stage-discharge curve at the downstream end of the Spook Hill FRS. The emergency spillway rating curve will be used in the existing and proposed conditions hydrologic and hydraulic models.

This rating curve, together with the stage-storage relationship for the reservoir, is required in the hydrologic model (HEC-1) to route the inflow design flood hydrograph through the emergency spillway structure.

The emergency spillway rating curve will also be used in the hydraulic analysis. FLDWAV, a generalized flood routing (unsteady flow simulation) model developed by the National Weather Service (NWS), will be used to develop the hydraulic models for the existing conditions along with the proposed Red Mountain Freeway improvements within the Spook Hill FRS. The emergency spillway rating curve will be used as the downstream boundary condition in the FLDWAV model.

## FORMULATION OF COMPUTATIONAL ALGORITHM

TR-39 pertains to the hydraulics of broad-crested spillways, both trapezoidal and rectangular. Even though broad-crested spillways may or may not have a hydraulic control section, TR-39 is primarily directed toward the evaluation of spillways having a control section.

In order to use the procedures and guidelines in TR-39, the hydraulic and geometric properties (i.e, length, width and side slope) of the emergency spillway must be identified. The following data was obtained from the as-built drawings and were used in the computations:

- The single emergency spillway for the Spook Hill FRS is a 260 feet (ft) wide Type C, reinforced concrete, straight drop spillway. The crest length of the spillway is approximately 29.5 feet.
- The crest elevation is 1,582.0 feet and the bottom elevation of the stilling basin is 1,568.0 feet.
- Side slopes along the spillway crest and at the exit channel are 2:1 (Horizontal to Vertical).

Additional data related to the design of the Emergency Spillway was taken from the "Evaluation of the Preliminary Design Report (1975)," as follows:

- The emergency spillway was assumed to have a control section at the downstream end of the broad-crested weir segment.
- The inlet channel of the spillway was assumed to have a horizontal slope extending from the control section to the reservoir (Case 1 spillway in TR-39).
- The spillway was assumed to have the same bottom width and side slopes throughout its length.

- The Manning's roughness coefficient (n) along the spillway crest was assumed to be equal to 0.04.

TR-39 considers spillways with a wide range of values for the following variables:

- Spillway bottom widths, b $(25\text{ ft} \le b \le 400\text{ ft})$,
- Side slopes of the spillway, z $(0 \le z \le 4)$,
- Manning's roughness n $(0.02 \le n \le 0.08)$, and
- Inlet channel length, L $(10\text{ ft} \le L \le 1000\text{ ft})$.

The as-built dimensions that were used to develop the existing Spook Hill FRS emergency spillway stage-discharge curve can be summarized as follows:

- Spillway bottom width, b = 260 feet,
- Side slope of the spillway, z = 2,
- Manning's roughness n = 0.04,
- Inlet channel length, L = 29.5 feet.

The emergency spillway rating curve is based on the following assumptions:

- The emergency spillway is assumed to have a control section (see Figure 1) at the downstream end of the broad-crested weir segment. Therefore, the depth of flow and the specific energy head at the control section for a discharge (Q) are equal to the critical depth and the critical specific energy head corresponding to Q, respectively.
- The flow velocities at the inlet of the emergency spillway are relatively low. Therefore, the energy grade line elevation is equal to the water surface elevation.
- The emergency spillway is assumed to operate as a broad-crested weir.
- All of the elevations reference the NGVD '29 datum.

Many of the parameters used in spillway design in TR-39 are evaluated for a preselected cross section, called the "reference section", by using the four principle drawings (ES-170, ES-171, ES-172, ES-173, and ES-174). The reference section for the Spook Hill FRS emergency spillway is assumed to have the following dimensions; b=100 feet, z=2 and n=0.04.

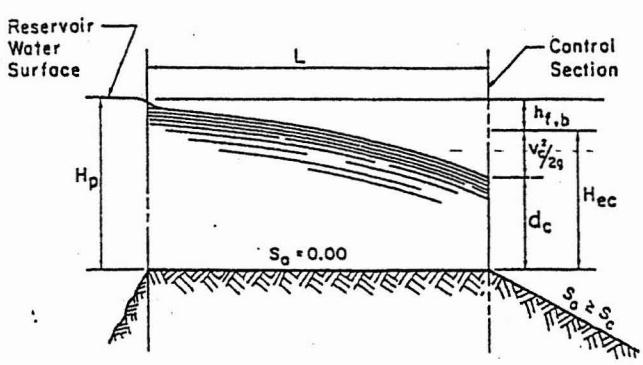



**Figure 1. Emergency Spillway Section**

The following two drawings were used in this white paper for emergency spillway rating computations:

- $H_p$ vs $H_{ec}$ with a family of spillway length, L-curves, for selected bottom profiles (ES-171).
- Q vs $H_{ec}$ with families of spillway bottom widths, b, and critical depths, $d_{c,q}$ (ES-174).

$H_{ec}$ = critical specific energy head at the control section, feet
$H_p$ = energy head of the water in the reservoir above the spillway crest, feet
Q = discharge, cfs
$d_{c,q}$ = critical depth corresponding to a discharge, Q, feet
$h_{f,b}$ = friction head loss in a spillway of length, L, and bottom width, b, feet

The only geometric difference between the Spook Hill FRS emergency spillway and the reference section in TR-39 is the spillway bottom width dimension. Therefore, an additional graph (ES-176) was included to evaluate the impact of the bottom width on the emergency spillway hydraulics.

The following step-by-step process was used to compute the emergency spillway stage-discharge curve. The upstream and downstream sections mentioned in the following paragraphs refer to the inlet and outlet of the broad-crested segment of the emergency spillway, respectively. Example calculations are provided in Appendix A.

**Step 1 – Upstream water-surface elevation, $H_p$**

- Establish water-surface elevations between the emergency spillway crest (1,582.0 feet) and top of the Spook Hill Dam (1,591.0 feet).

**Step 2 – Downstream water-surface elevation, $H_{ec}$**

- Use ES-171 (Sheet 1 of 10) to compute the corresponding water-surface elevation at the control section.

**Step 3 – Effect of bottom width on friction head loss**

- Compute the friction head loss for the reference section using the following equation:

$$h_{f,100} = H_p - H_{ec}$$

Where:

$h_{f,100}$ = friction head loss in a spillway length, L, and bottom width of 100 feet

- Adjust the friction head loss for the Spook Hill emergency spillway bottom width (260 feet) using the guidelines in TR-39 (ES-176, Sheet 4 of 13).

- Compute the corresponding $H_{ec}$ using the following equation:

$$H_{ec} = H_p - h_{f,260}$$

**Step 4 – Discharge, Q**

- Compute the discharge through the emergency spillway using the guidelines in TR-39 (ES-174, Sheets 6 of 9 and 9 of 9).
- Use the flow depth in Step 3 and the spillway bottom width of 260 feet.

## RESULTS AND RECOMMENDATIONS

An emergency spillway stage-discharge curve is required for the existing and proposed condition hydrologic and hydraulic models for the Spook Hill FRS. The stage-discharge curve developed by the SCS was presented on the original spillway as-built plans, but the supporting calculations could not be located for this analysis.

The proposed methodology presented in this white paper uses the procedures and guidelines provided in TR-39 to compute the Spook Hill FRS emergency spillway stage-discharge relationship. As shown in the summary tables in Appendix A, the change in the emergency spillway width, from the Reference Section in TR-39, has a minor effect on the friction head loss.

A comparison between the SCS as-built emergency rating curve and the rating curve developed by DMJM+HARRIS is provided in the following table. As shown in the table, both of the curves present similar stage-discharge characteristics. Therefore, it is recommended that the emergency spillway stage-discharge rating curve presented in this white paper be used for the Spook Hill FRS hydrologic and hydraulic analyses.

**Summary of Results**

| Stage | Discharge | |
|---|---|---|
| | Recommended | SCS* |
| (feet) | (cfs) | (cfs) |
| 1582 | 0 | 0 |
| 1584 | 1,860 | 2,250 |
| 1585 | 3,700 | 4,100 |
| 1586 | 5,900 | 6,150 |
| 1588 | 11,600 | 11,000 |
| 1590 | 18,000 | 17,850 |
| 1591 | 21,800 | 21,000 |

*Based on the as-built drawings

## REFERENCES

Ertec Western, Inc., "Phase I Inspection Report for Spook Hill Retarding Dam, I.D. No. AZ00175," August 1981.

Soil Conservation Service, "National Engineering Handbook, Section 4, Hydrology," August 1972.

Soil Conservation Service, "Hydrology Buckhorn Mesa Watershed Spook Hill Reservoir," (Evaluation of Preliminary Design Report), May 1975.

Soil Conservation Service, "Buckhorn-Mesa WPP, AZ, Spook Hill FRS, Final Design," December 1976.

Soil Conservation Service, "Hydraulics of Broad Crested Spillways," Technical Release No. 39 (TR-39), 1968.

# APPENDIX A

# EXAMPLE CALCULATIONS

**Spook Hill FRS**
**Emergency Spillway**
**Stage-Discharge Curve**

**Table 1. Emergency Spillway Stage-Discharge Relationship**

| Stage (ft) | Elevation* (ft) | Hp (ft) | $H_{ec}$** (ft) | $h_{f,100}$ (ft) | $h_{f,260}$*** (ft) | $H_{ec}$**** (ft) | Discharge***** (cfs) |
|---|---|---|---|---|---|---|---|
| 1582 | 1582 | 0 | 0 | 0.00 | | 0 | 0 |
| 1584 | 1582 | 2 | 1.75 | 0.25 | 0.25 | 1.75 | 1,860 |
| 1585 | 1582 | 3 | 2.74 | 0.26 | 0.27 | 2.73 | 3,700 |
| 1586 | 1582 | 4 | 3.73 | 0.27 | 0.27 | 3.73 | 5,900 |
| 1588 | 1582 | 6 | 5.8 | 0.20 | 0.20 | 5.80 | 11,600 |
| 1590 | 1582 | 8 | 7.75 | 0.25 | 0.25 | 7.75 | 18,000 |
| 1591 | 1582 | 9 | 8.75 | 0.25 | 0.25 | 8.75 | 21,800 |

* Emergency Spillway Crest Elevation
** Use ES-171, Sheet 1 of 10
*** Use Table 2
**** $H_{ec} = H_p - h_{f,260}$
***** Use ES-174 (Sheets 6 of 9 and 9 of 9)

**Table 2. Friction Head Loss Adjustment**

| $H_{ec}$ (ft) | $h_{f,100}$ (ft) | $h_{f,260}$* (ft) |
|---|---|---|
| 1.75 | 0.2500 | 0.2510 |
| 2.74 | 0.2600 | 0.2715 |
| 3.73 | 0.2700 | 0.2724 |
| 5.8 | 0.2000 | 0.2021 |
| 7.75 | 0.2500 | 0.2527 |
| 8.75 | 0.2500 | 0.2527 |

* Use Tables 3 and 4

**Table 3. Friction Head Loss Adjustment**

| $H_{ec}$ (ft) | L (ft) | b (ft) | $(h_{f,25} / h_{f,100})$* | $h_{f,100}$ (ft) | $h_{f,25}$ (ft) | $h_{f,25}$** (ft) |
|---|---|---|---|---|---|---|
| 1.75 | 10 | 25 | 1.0268 | 0.25 | 0.2567 | |
| | 50 | 25 | 1.0215 | | 0.2554 | 0.2561 |
| 2.74 | 10 | 25 | 1.0390 | 0.26 | 0.2805 | |
| | 50 | 25 | 1.0315 | | 0.2785 | 0.2795 |
| 3.73 | 10 | 25 | 1.0485 | 0.27 | 0.2831 | |
| | 50 | 25 | 1.0395 | | 0.2807 | 0.2819 |
| 5.8 | 10 | 25 | 1.0652 | 0.20 | 0.2130 | |
| | 50 | 25 | 1.0524 | | 0.2105 | 0.2118 |
| 7.75 | 10 | 25 | 1.0760 | 0.25 | 0.2690 | |
| | 50 | 25 | 1.0612 | | 0.2653 | 0.2672 |
| 8.75 | 10 | 25 | 1.0820 | 0.25 | 0.2705 | |
| | 50 | 25 | 1.0645 | | 0.2661 | 0.2683 |

* Use ES-176, Sheet 4 of 13
** Length = 29.5 ft, Interpolate between L=10 ft and L=50 ft

**Table 4. Friction Head Loss Adjustment**

| $H_{ec}$ (ft) | L (ft) | b (ft) | $(h_{f,400} / h_{f,100})$* | $h_{f,100}$ (ft) | $h_{f,400}$ (ft) | $h_{f,400}$** (ft) |
|---|---|---|---|---|---|---|
| 1.75 | 10 | 400 | 0.9920 | 0.25 | 0.2480 | |
| | 300 | 400 | 0.9945 | | 0.2486 | 0.2480 |
| 2.74 | 10 | 400 | 0.9875 | 0.26 | 0.2666 | |
| | 300 | 400 | 0.9912 | | 0.2676 | 0.2667 |
| 3.73 | 10 | 400 | 0.9882 | 0.27 | 0.2668 | |
| | 300 | 400 | 0.9838 | | 0.2656 | 0.2667 |
| 5.8 | 10 | 400 | 0.9822 | 0.20 | 0.1964 | |
| | 300 | 400 | 0.9758 | | 0.1952 | 0.1964 |
| 7.75 | 10 | 400 | 0.9768 | 0.25 | 0.2442 | |
| | 300 | 400 | 0.9688 | | 0.2422 | 0.2441 |
| 8.75 | 10 | 400 | 0.9744 | 0.25 | 0.2436 | |
| | 300 | 400 | 0.9655 | | 0.2414 | 0.2434 |

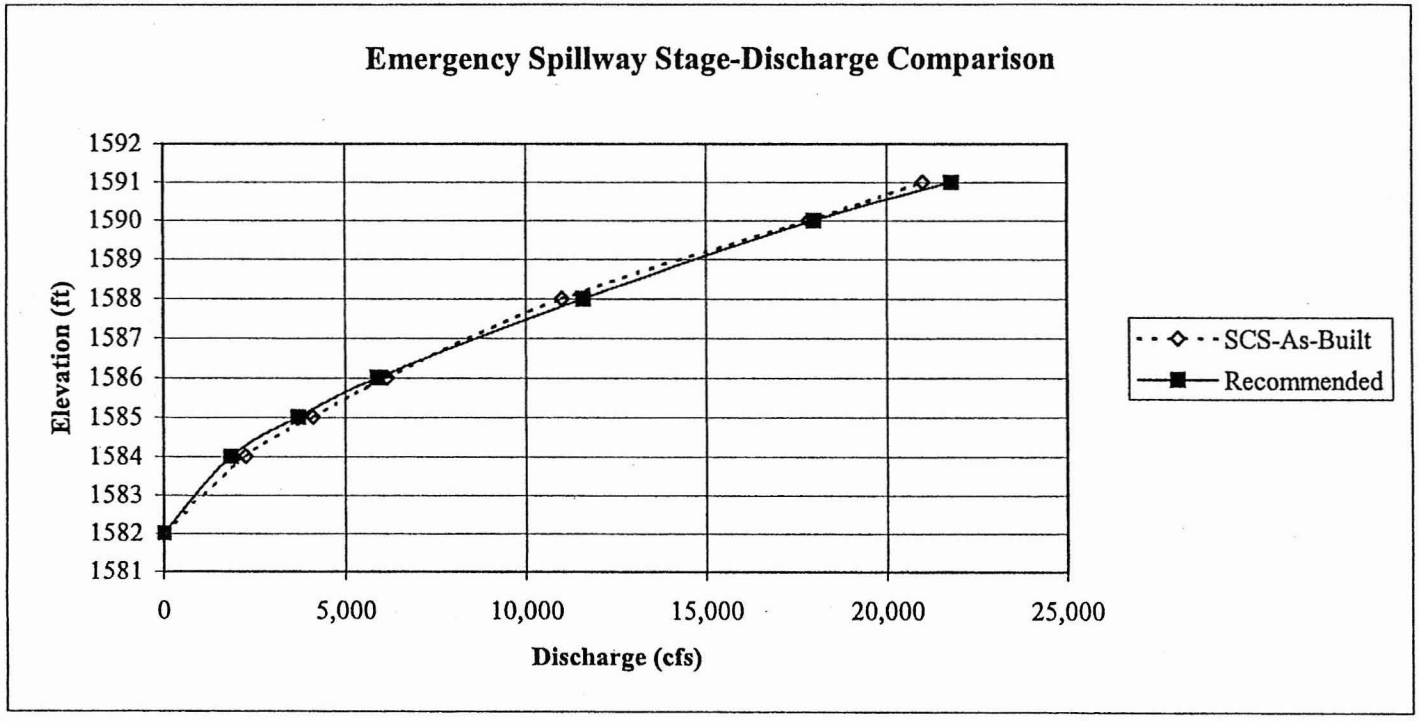
* Use ES-176, Sheet 4 of 13
** Length = 29.5 ft, Interpolate between L=10 ft and L=300 ft

**Spook Hill FRS**
**Emergency Spillway**
**Stage-Discharge Curve**

**Stage-Discharge Summary**

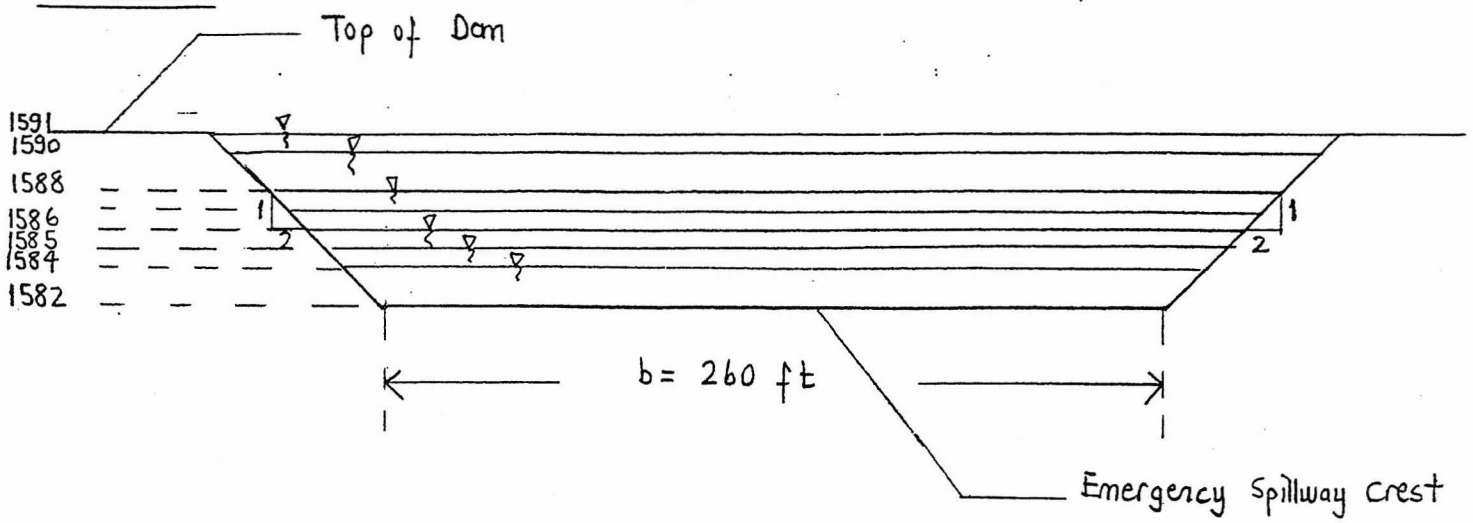
| Stage (ft) | Discharge Recommended (cfs) | Discharge SCS* (cfs) |
|---|---|---|
| 1582 | 0 | 0 |
| 1584 | 1,860 | 2,250 |
| 1585 | 3,700 | 4,100 |
| 1586 | 5,900 | 6,150 |
| 1588 | 11,600 | 11,000 |
| 1590 | 18,000 | 17,850 |
| 1591 | 21,800 | 21,000 |

* Based on the as-built drawings



| DMJM | PROJECT: RED MOUNTAIN FREEWAY (POWER RD - UNIVERSITY DR.) | JOB NO. | SHEET 1 of 4 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 08/02/01 |
| SUBJECT: Emergency Spillway Stage-Discharge Curve | | CHECKED BY JRM | DATE 8/6/01 |

## STEP 1 Upstream Water-Surface Elevation, $H_p$




Establish water-surface elevations between

the Emergency Spillway Crest (1,582.0 ft), and

the Top of Dam (1,591.0 ft)

## STEP 2 Downstream Water-Surface Elevation, $H_{ec}$

Use TR-39 (ES-171, sheet 1 of 10) to compute $H_{ec}$

Use the $H_p$ value in Step 1, and

Emergency Spillway Length, L = 29.5 ft.

The numerical values are summarized in Table 1.

| DMJM | PROJECT: | JOB NO. | SHEET 2 of 4 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 08/02/01 |
| SUBJECT: | | CHECKED BY JRM | DATE 8/5/01 |

## STEP 3 Effect of bottom width on friction head loss

- Compute $h_{f,100} = H_p - H_{ec}$

  As shown in Table 1, $H_p = 2.0$ ft $H_{ec} = 1.75$ ft

  $$h_{f,100} = 0.25 \text{ ft.}$$

- Use TR-39 ( ES-176, Sheet 4 of 13) to adjust the friction head loss

→ The friction head loss ratios, $\left(\frac{h_{f,b}}{h_{f,100}}\right)$, provided in this graph are a function of L, b and $H_{ec}$.

→ Using the $H_{ec}$ computed in Step 2, select the friction ratios for

- b = 25 ft ( L = 10' and L = 50' provided)
- b = 400 ft ( L = 10' and L = 300' provided)

→ As shown in Tables 3 and 4, compute $h_{f,25}$ and $h_{f,400}$:

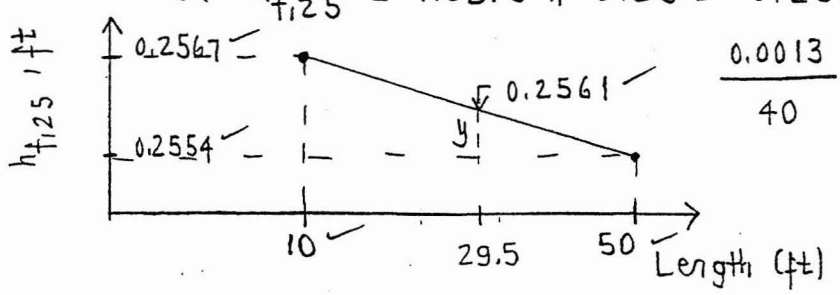
- From ES-176, Sheet 4 of 13

  For $H_{ec} = 1.75$ ft, L = 10 ft b = 25 ft $\Rightarrow \left(\frac{h_{f,25}}{h_{f,100}}\right) = 1.0268$

  $\therefore h_{f,25} = 1.0268 * 0.25 = 0.2567$ ft (L = 10 ft)

  For $H_{ec} = 1.75$ ft, L = 50 ft b = 25 ft $\Rightarrow \left(\frac{h_{f,25}}{h_{f,100}}\right) = 1.0215$

  $\therefore h_{f,25} = 1.0215 * 0.25 = 0.2554$ ft. (L = 50 ft)




$$\frac{0.0013}{40} = \frac{y}{20.5} \Rightarrow y = 6.66 \times 1$$

| DMJM | PROJECT: | JOB NO. | SHEET 3 of 4 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 08/02/01 |
| SUBJECT: | | CHECKED BY [illegible] | DATE 8/5/01 |

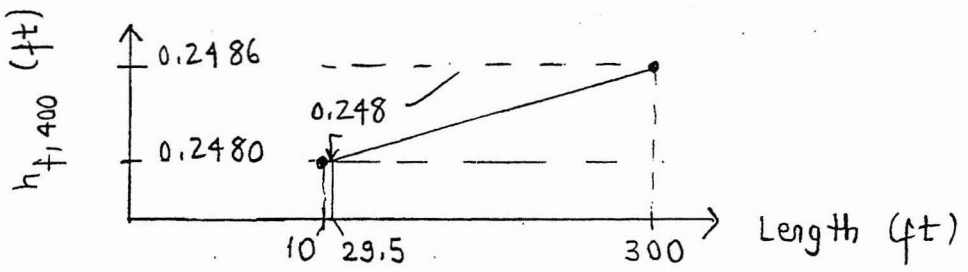
- From ES-176, Sheet 4 of 13

For $H_{ec} = 1.75$ ft, $L = 10$ ft $b = 400$ ft $\Rightarrow \left(\frac{h_{f,400}}{h_{f,100}}\right) = 0.9920$

$\therefore h_{f,400} = 0.9920 * 0.25 = 0.248$ ft ($L = 10$ ft)

For $H_{ec} = 1.75$ ft, $L = 300$ ft $b = 400$ ft $\Rightarrow \left(\frac{h_{f,400}}{h_{f,100}}\right) = 0.9945$

$\therefore h_{f,400} = 0.9945 * 0.25 = 0.2486$ ft ($L = 300$ ft)

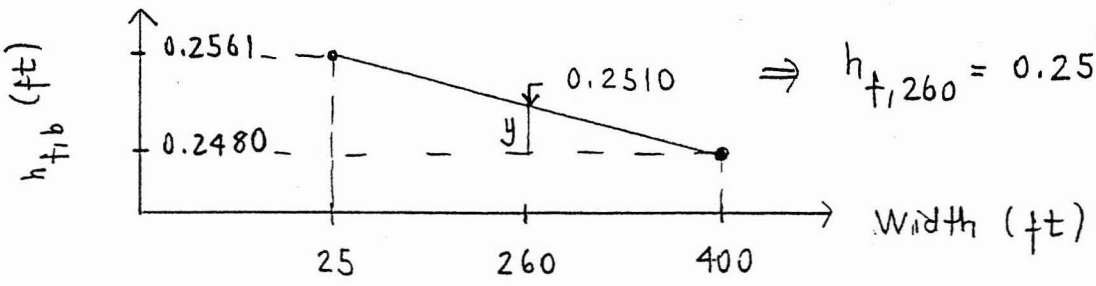



$$\frac{0.0006}{290} = \frac{y}{19.5} \rightarrow y = 4.03 * 10^{-5} \text{ ft}$$

Therefore

For $L = 29.5$ ft $h_{f,25} = 0.2561$ ft

$h_{f,400} = 0.2480$ ft.




$\Rightarrow h_{f,260} = 0.251$ ft.

$$\frac{0.0081}{375} = \frac{y}{140} \rightarrow y = 3.02 * 10^{-3} \text{ ft}$$

• Compute the corresponding $H_{ec}$ (for b = 260 ft)

$$H_{ec} = H_p - h_{f,260}$$
$$= 2 - 0.25$$
$$\cong 1.75 \text{ ft.}$$

STEP 4 Discharge, Q

Compute the discharge through the emergency spillway using TR-39 (ES-174, sheet 6 of 9)

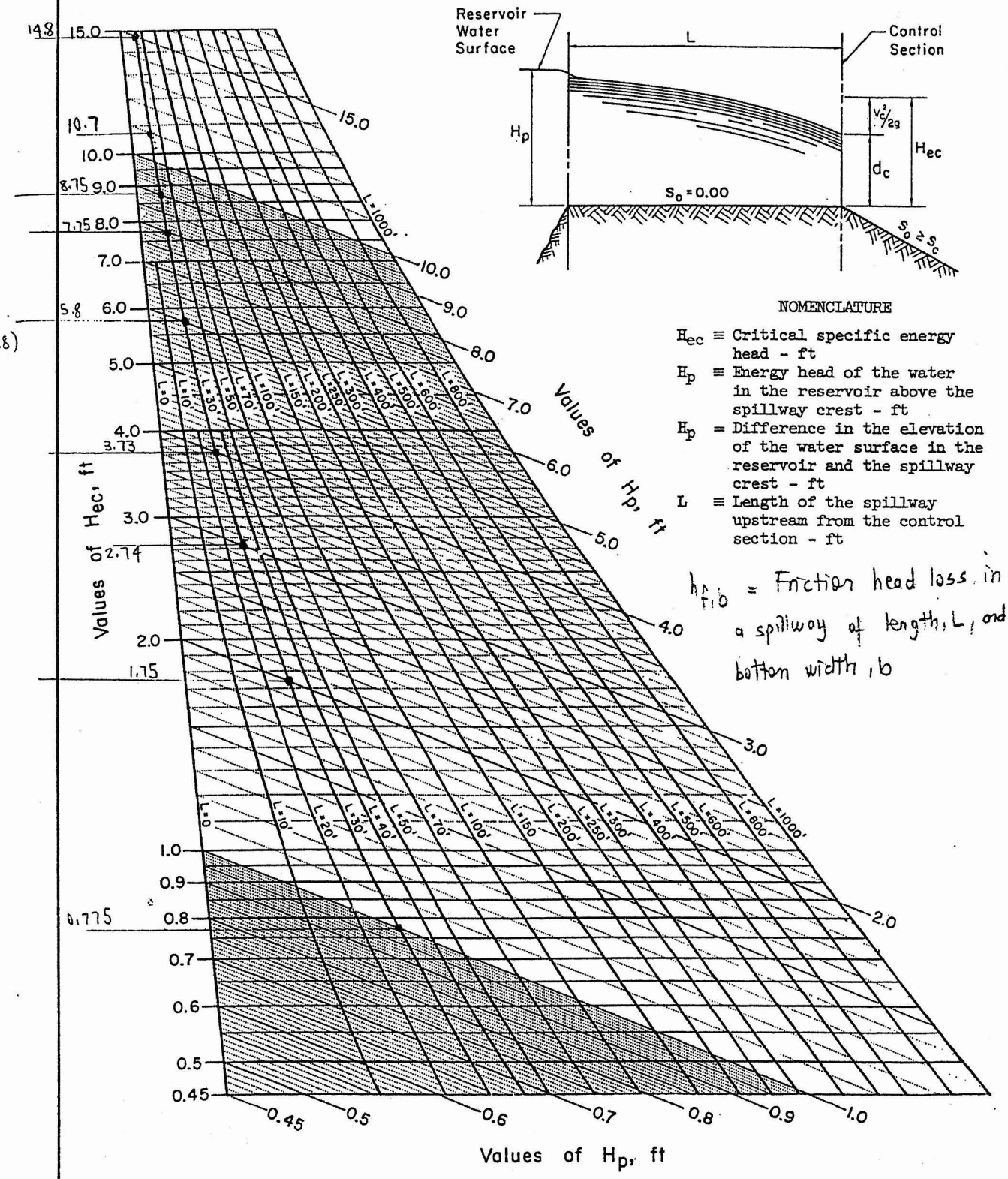
For $H_{ec} = 1.75$ ft, b = 260 ft $\Rightarrow$ Q = 1,860 cfs.

Reference Section

# SPILLWAYS: Hec vs Hp for Various Lengths, L

b = 100 ft
z = 2
n = 0.04

Case 1




40 scale
1.5 ≡ 1'
0.3 0.2 (5.8)

NOMENCLATURE

$H_{ec}$ ≡ Critical specific energy head - ft

$H_p$ ≡ Energy head of the water in the reservoir above the spillway crest - ft

$H_p$ = Difference in the elevation of the water surface in the reservoir and the spillway crest - ft

L ≡ Length of the spillway upstream from the control section - ft

$h_{f1b}$ = Friction head loss in a spillway of length, L, and bottom width, b

| REFERENCE | U. S. DEPARTMENT OF AGRICULTURE<br>SOIL CONSERVATION SERVICE<br>ENGINEERING DIVISION - DESIGN UNIT | STANDARD DWG. NO.<br>ES- 171<br>SHEET 1 OF 10<br>DATE 2-67 |
|---|---|---|

# SPILLWAYS: Effect of b on Friction Head Loss

Case I
n = 0.04
z = 2

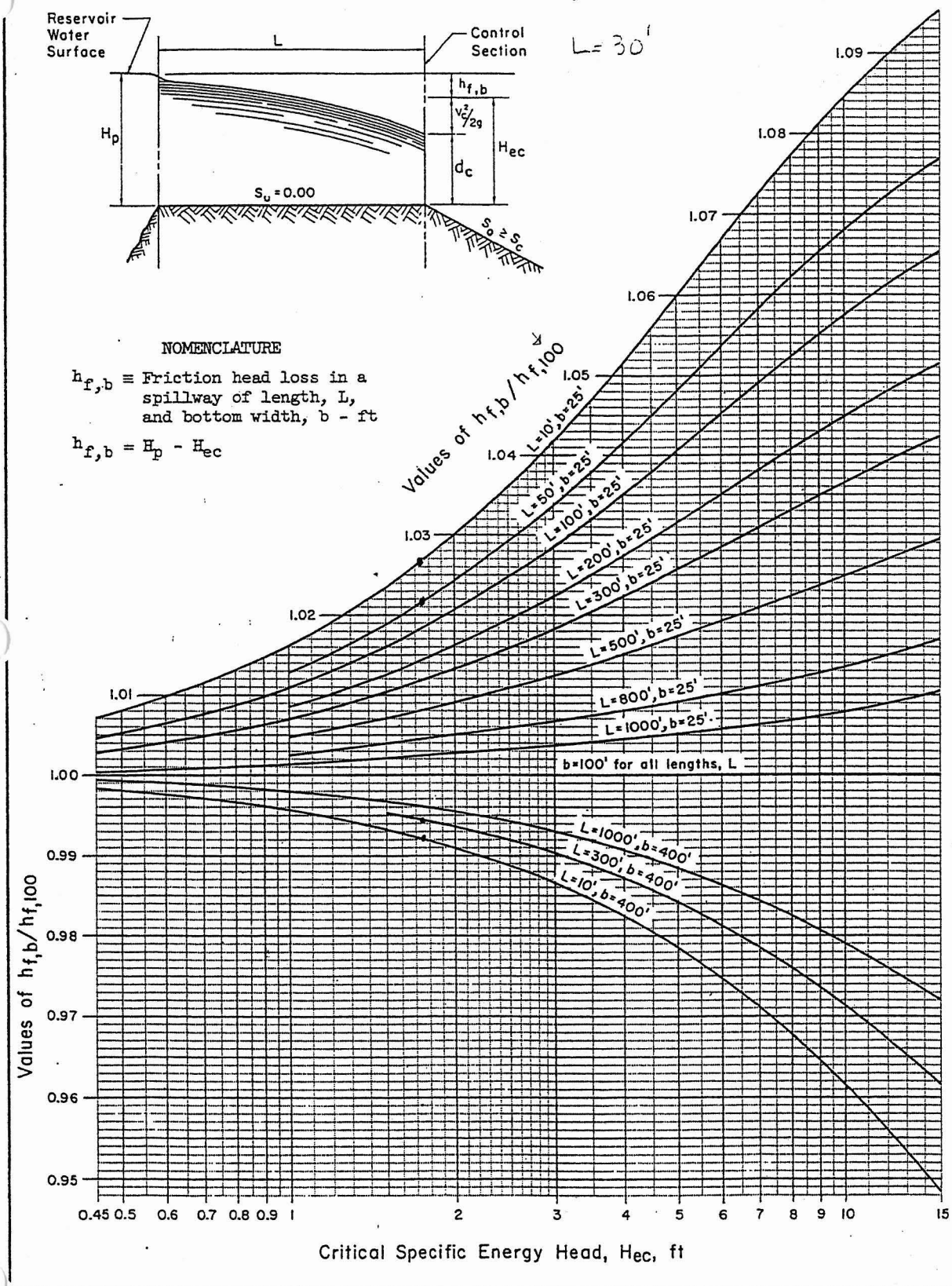
b = 200'
L = 30'




NOMENCLATURE

$h_{f,b}$ ≡ Friction head loss in a spillway of length, L, and bottom width, b - ft

$h_{f,b} = H_p - H_{ec}$



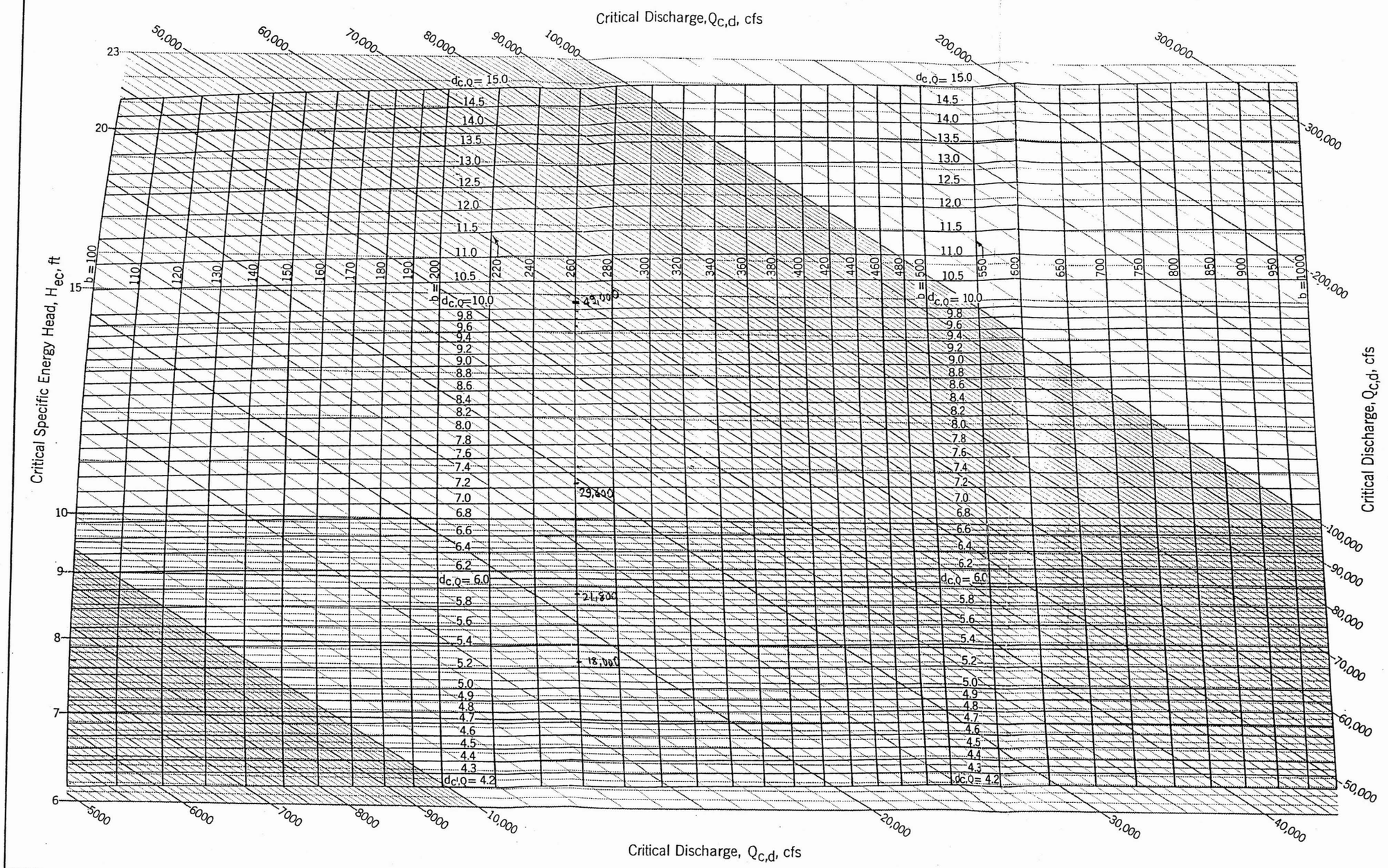

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN UNIT

STANDARD DWG. NO.
ES- 176
SHEET 4 OF 13
DATE 2-67

# HYDRAULICS: $H_{ec}$ vs $Q_{c,d}$ for Various Bottom Widths, b

$Z = 2$
$100 \text{ ft} \le b \le 1000 \text{ ft}$
$4.2 \text{ ft} \le d_{c,Q} \le 15 \text{ ft}$



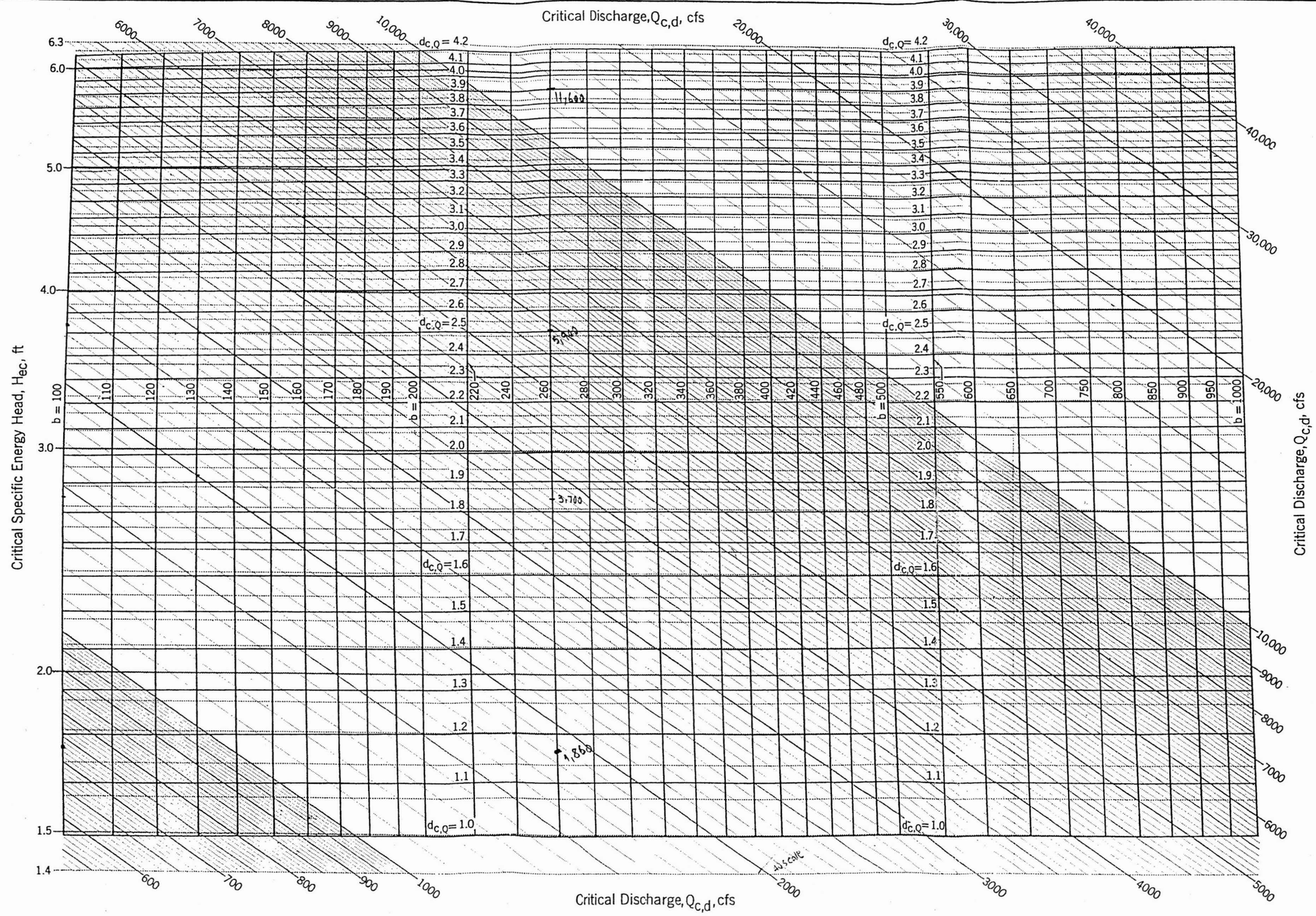

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN UNIT

STANDARD DWG. NO.
ES - 174
SHEET 9 OF 9
DATE 11-67

# HYDRAULICS: $H_{ec}$ vs $Q_{c,d}$ for Various Bottom Widths, b

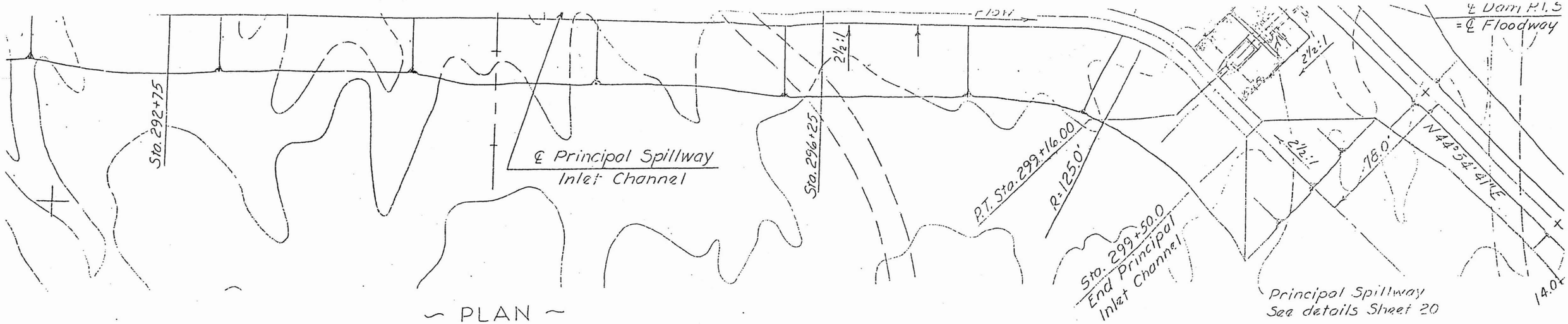
Z = 2
100 ft ≤ b ≤ 1000 ft
1.0 ft ≤ $d_{c,Q}$ ≤ 4.2 ft




REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN UNIT

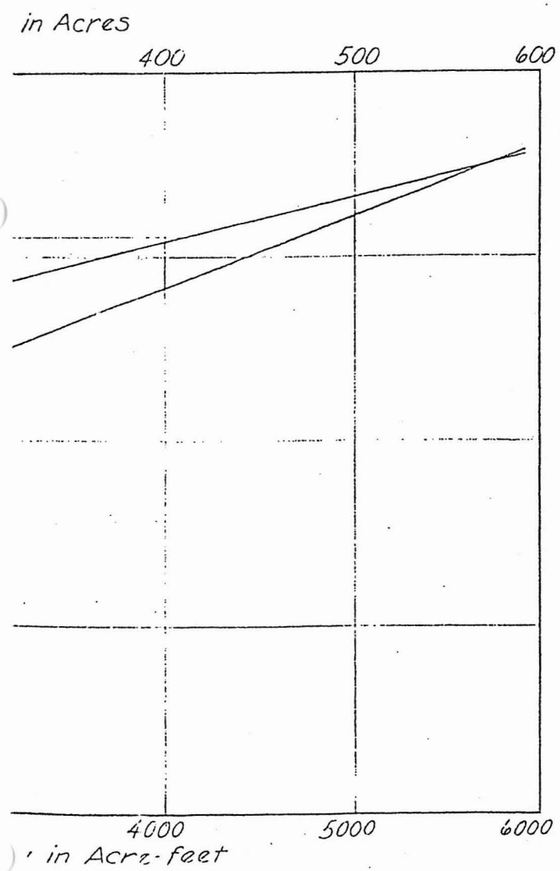
STANDARD DWG. NO.
ES - 174
SHEET 6 OF 9
DATE 11-67



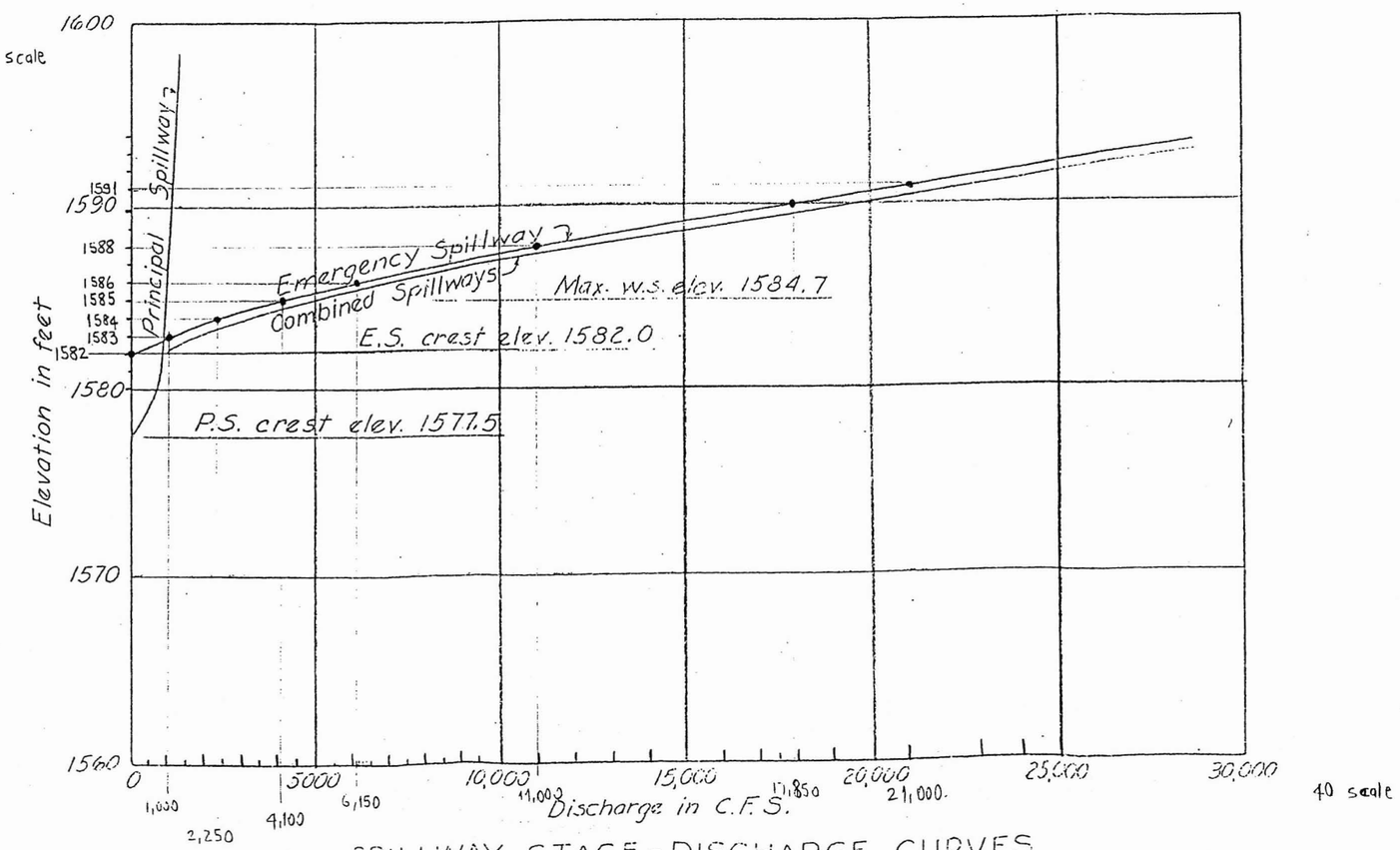

~ PLAN ~

50 0 50 100
SCALE IN FEET

SCS ASBUILT




STAGE STORAGE CURVE




SPILLWAY STAGE-DISCHARGE CURVES

U.

Designed
Drawn
Traced
Checked

# Appendix D3

## Spook Hill Floodwater Retarding Structure (FRS)
## Signal Butte Floodway Inflow Hydrograph

# SPOOK HILL FLOODWATER RETARDING STRUCTURE (FRS)
# SIGNAL BUTTE FLOODWAY INFLOW HYDROGRAPH

**ABSTRACT:** The purpose of this white paper is to present a recommended approach to define the inflow hydrograph to the Spook Hill Floodwater Retarding Structure (FRS) from the Signal Butte Floodway. The inflow hydrograph is computed using the uncontrolled drainage area contributing to the Signal Butte Floodway, and the area below the Pass Mountain Diversion Structure and the Signal Butte FRS. Supporting calculations defining the inflow hydrograph to the Spook Hill FRS from the Signal Butte Floodway are provided.

## INTRODUCTION

The Signal Butte Floodway inflow hydrograph presented in this white paper is recommended to be used to define the inflow design flood for the Spook Hill FRS. The inflow hydrograph is required to model the contribution of the upper segments of the Buckhorn Mesa watershed, in terms of the peak discharge and volume, into the Spook Hill FRS.

The inflow hydrograph will also be used to define the upstream boundary condition in the hydraulic analysis of the Spook Hill FRS. FLDWAV, a generalized flood routing model developed by the National Weather Service (NWS), will be used to define the hydraulics of the Spook Hill FRS for existing and proposed conditions with the Red Mountain Freeway constructed within the flood pool.

## APPROACH

Key factors to the development of the Signal Butte inflow hydrograph are summarized as follows:

- Contributing area upstream of the Spook Hill FRS (subbasins F-I in Figure 1),
- Hydrologic parameters for the contributing area,
- Diversion of flow hydrographs in excess of the Signal Butte Floodway capacity, and
- Routing parameters along the Signal Butte Floodway.

### Contributing Area

As recommended in the original design, the entire uncontrolled drainage area below the Pass Mountain Diversion Structure and Signal Butte FRS was considered to be the contributing drainage area (see Figure 1). The proposed subbasin boundaries are similar those established with the original design. The outflow from the Signal Butte FRS principal spillway was modeled using a direct input hydrograph in the hydrologic model (HEC-1).

### Hydrologic Parameters

The methodology presented in the Flood Control District of Maricopa County (FCDMC) Hydrology Manual (1995) was used to define the hydrologic parameters for the contributing subbasins along the Signal Butte Floodway. The parameters used in the hydrologic model are summarized as follows:

- The Probable Maximum Flood (PMF) event was used for the hydrologic analysis. The depth and distribution of the PMF event documented in Technical Report No. 1 (Draft, January 2001) were used in the hydrologic model;
- Infiltration losses were determined using Green and Ampt methodology;
- Rainfall excess was transformed into direct runoff using the Clark Unit Hydrograph methodology;

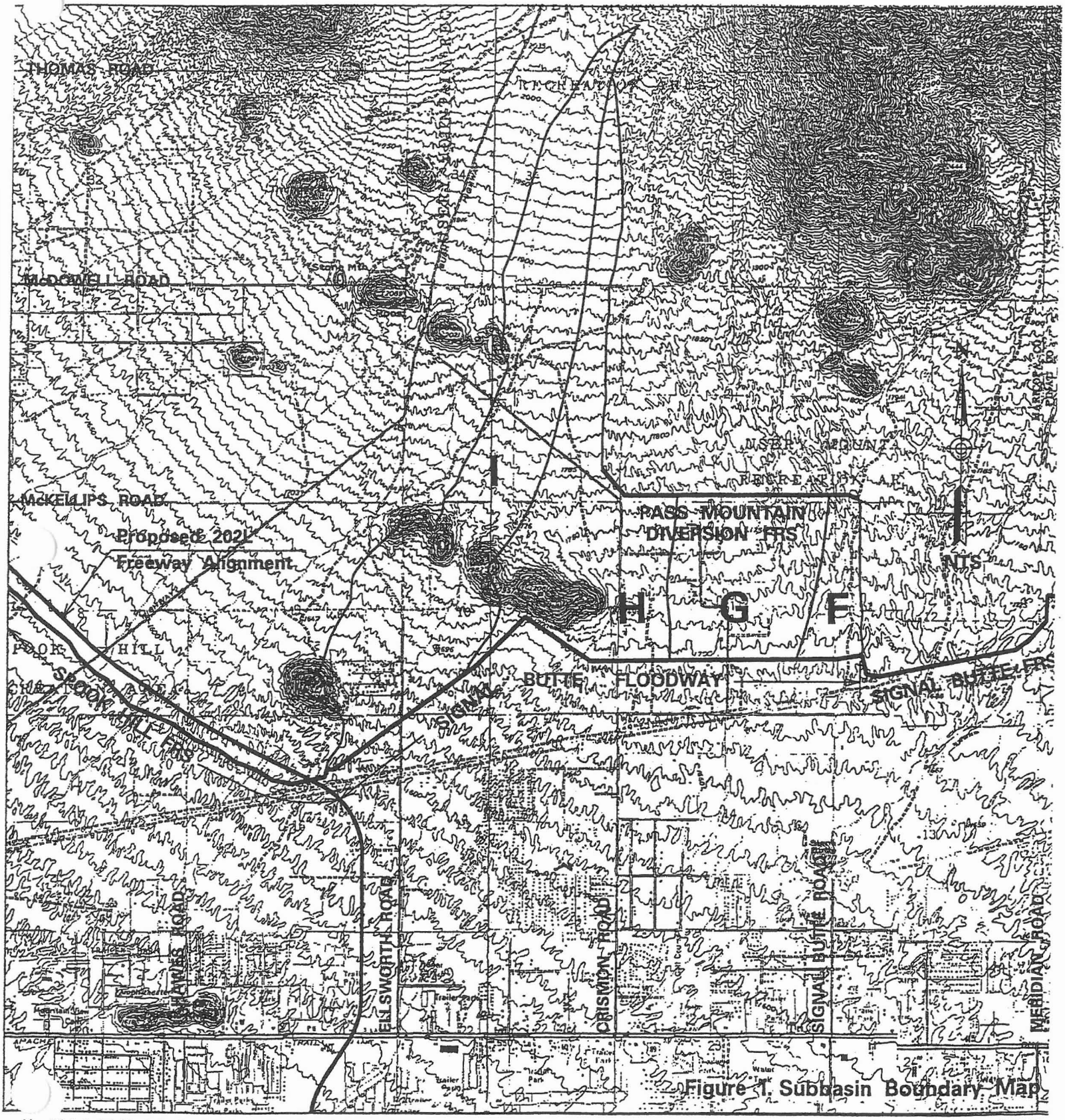



Figure 1. Subbasin Boundary Map

J:\rm06\design\drn\hydrology\technical papers\tp2\Figure 1.dgn

DMJM + HARRIS

- Time of concentration was computed using the new numerical procedure presented in the first DMJM+HARRIS white paper, "Time of Concentration, A Modification of the TR-55 methodology"; and
- HEC-1 default values were used for the time-area relationship.

Diversions

The geometric and roughness characteristics along the Signal Butte Floodway, documented by as-built plans, were used to compute the floodway capacity. Flows in excess of this capacity were diverted out of the hydrologic model (HEC-1).

Routing Parameters

The Signal Butte Floodway was hydrologically routed using normal depth methods. Routing parameters were developed using as-built plans for the floodway and methodologies presented in the FCDMC Hydrology Manual. Figure 2 presents a routing schematic for the area contributing to the Signal Butte Floodway.

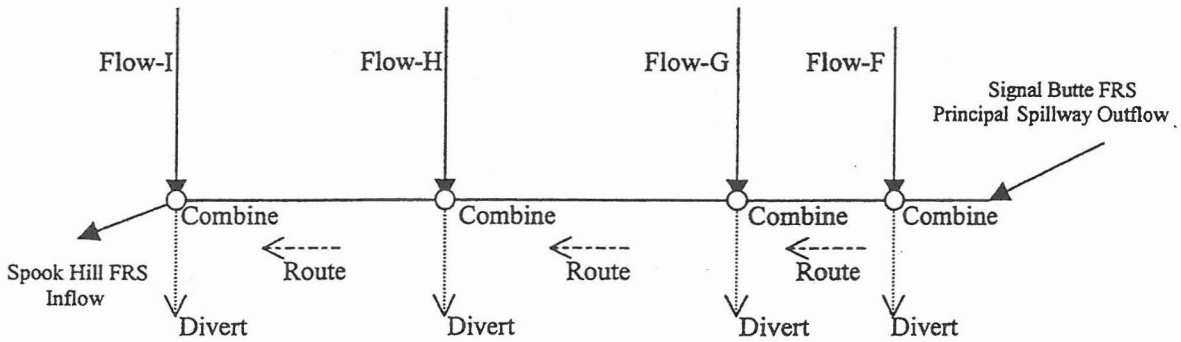



**Figure 2. Signal Butte Floodway Routing Schematic**

It should be noted that the outflow from the Signal Butte FRS was conservatively assumed to be a constant 157 cfs as presented in the "Evaluation of Preliminary Design Report". An inflow hydrograph from the Signal Butte Floodway was not documented. The peak flow estimate, at the inlet of the Spook Hill FRS, computed by the SCS was determined using the following process:

- Use the maximum principal spillway outflow from Signal Butte FRS as a base flow into the Signal Butte Floodway;
- Route the 100-year 24-hour storm down the Signal Butte Floodway using TR-20 methodology; and
- Add 30% to this 100-year, 24-hour design discharge to obtain the freeboard design capacity of the floodway.

This approach resulted in a peak flow estimate of 2,888 cfs at the inlet of the Spook Hill FRS and does not reflect the as-built Signal Butte Floodway capacity.

## RESULTS AND RECOMMENDATIONS

Using the approach presented in this white paper, the resulting peak flow at the inlet of the Spook Hill FRS is estimated to be 2,872 cfs. The proposed inflow hydrograph is based on channel geometry and roughness characteristics for the as-built Signal Butte Floodway. Therefore, it is recommended that the inflow hydrograph presented in this white paper be used for the Spook Hill FRS hydrologic and hydraulic analyses.

## REFERENCES

Flood Control District of Maricopa County, "Drainage Design Manual for Maricopa County, Arizona, Volume I, Hydrology," 1995.

Flood Control District of Maricopa County, "Drainage Design Management System, User's Manual," 1999.

Soil Conservation Service, "Hydrology, Buckhorn-Mesa Watershed, Spook Hill Reservoir," (Evaluation of Preliminary Design Report), May 1975.

Soil Conservation Service, "Buckhorn-Mesa WPP, Spook Hill FRS, Final Design," December 1976.

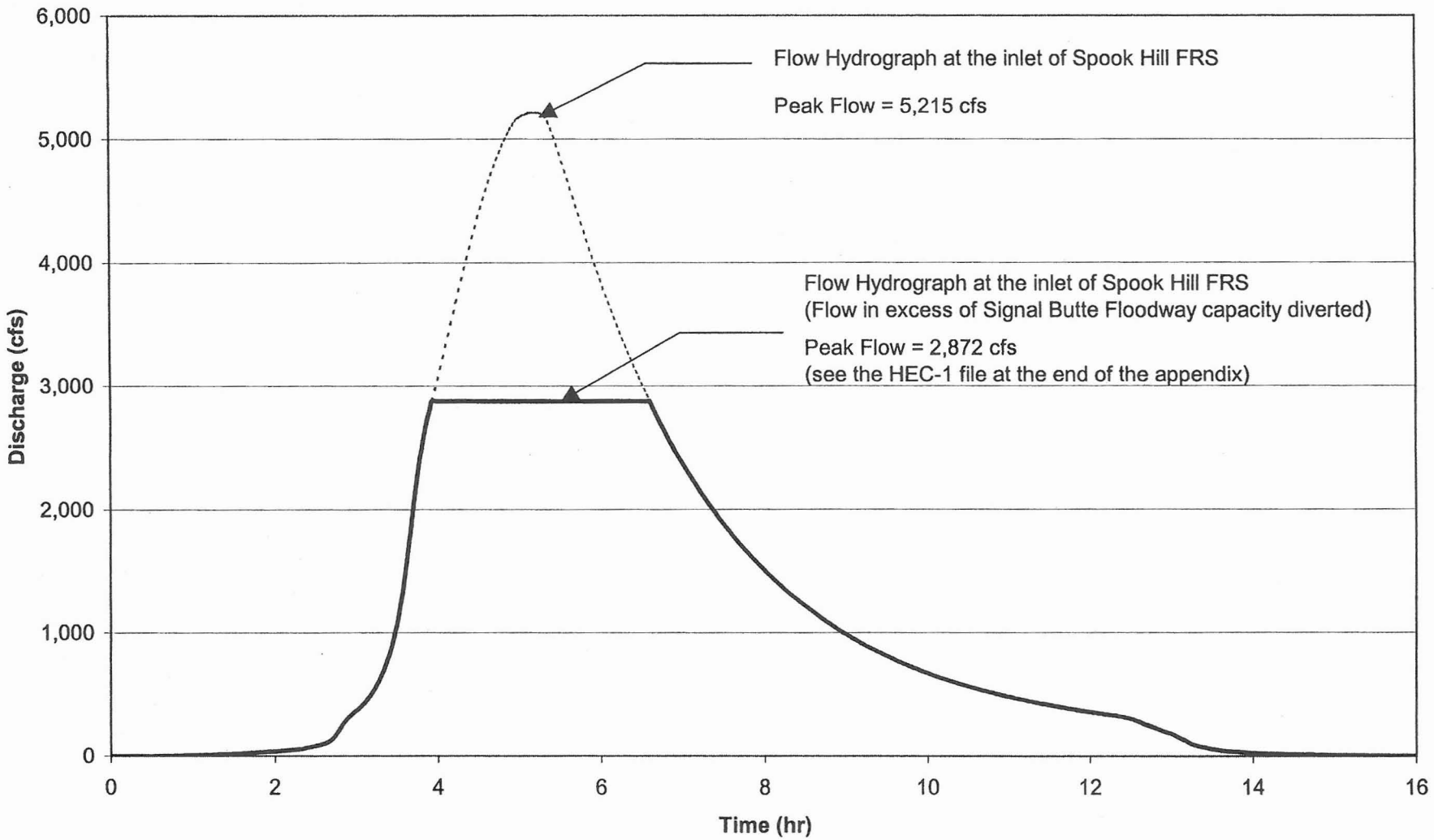
Soil Conservation Service, "Buckhorn-Mesa Watershed Protection and Flood Protection Project, Plans for the Construction of Signal Butte Floodway,". 1983.

U.S. Army Corps of Engineers, "Hydrometeorological Report No. 49," September 1977.

# APPENDIX A

# EXAMPLE CALCULATIONS

## SPOOK HILL FRS
## Signal Butte Floodway Inflow Hydrograph



## SPOOK HILL FRS
## Signal Butte Floodway Inflow Hydrograph

### Table 1. Time of Concentration for Subbasin F

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.45 | 1,590 | 0.0133 | 0.052 | 1,650 | 0.48 | 0.46 | 0.0159 | 2.16 | 2,510 | 0.32 | 0.71 | 1.03 | 0.900 |
| 2 | 0.45 | 531 | 0.0133 | 0.052 | 1,650 | 0.25 | 0.35 | 0.0159 | 1.78 | 2,510 | 0.39 | 0.71 | 1.10 | 0.966 |
| 3 | 0.45 | 504 | 0.0133 | 0.052 | 1,650 | 0.24 | 0.34 | 0.0159 | 1.77 | 2,510 | 0.39 | 0.71 | 1.10 | 0.969 |

### Table 2. Time of Concentration for Subbasin G

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.44 | 4,324 | 0.0143 | 0.052 | 3,230 | 0.57 | 0.50 | 0.0175 | 2.39 | 2,850 | 0.33 | 0.71 | 1.04 | 0.463 |
| 2 | 0.44 | 2,546 | 0.0143 | 0.052 | 3,230 | 0.41 | 0.43 | 0.0175 | 2.14 | 2,850 | 0.37 | 0.71 | 1.08 | 0.482 |
| 3 | 0.44 | 2,474 | 0.0143 | 0.052 | 3,230 | 0.41 | 0.42 | 0.0175 | 2.13 | 2,850 | 0.37 | 0.71 | 1.08 | 0.483 |

### Table 3. Time of Concentration for Subbasin H

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.33 | 6,913 | 0.0173 | 0.052 | 2,755 | 0.78 | 0.56 | 0.0227 | 2.92 | 12,770 | 1.21 | 0.56 | 1.77 | 1.697 |
| 2 | 0.33 | 1,982 | 0.0173 | 0.052 | 2,755 | 0.37 | 0.35 | 0.0227 | 2.15 | 12,770 | 1.65 | 0.56 | 2.21 | 2.168 |
| 3 | 0.33 | 1,617 | 0.0173 | 0.052 | 2,755 | 0.33 | 0.33 | 0.0227 | 2.06 | 12,770 | 1.72 | 0.56 | 2.28 | 2.245 |
| 4 | 0.33 | 1,570 | 0.0173 | 0.052 | 2,755 | 0.32 | 0.33 | 0.0227 | 2.05 | 12,770 | 1.73 | 0.56 | 2.29 | 2.256 |

### Table 4. Time of Concentration for Subbasin I

| Iteration No. | Upstream Boundary | Downstream Boundary | | | | | Average Channel Flow Parameters | | | | Travel Time | | Time of Concentration | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Depth (ft) | Discharge (cfs) | Bottom Slope (ft/ft) | Manning's n | Effective Basin Width (ft) | Flow Depth (ft) | Average Depth (ft) | Average Slope (ft/ft) | Average Velocity (ft/s) | Average Length (ft) | Channel Flow (hr) | Sheet and Shallow Concentrated Flow (hr) | Tc (hr) | R (hr) |
| 1 | 0.49 | 7,610 | 0.0250 | 0.052 | 3,410 | 0.65 | 0.57 | 0.0250 | 3.12 | 12,168 | 1.08 | 0.87 | 1.96 | 1.704 |
| 2 | 0.49 | 2,758 | 0.0250 | 0.052 | 3,410 | 0.36 | 0.42 | 0.0250 | 2.55 | 12,168 | 1.32 | 0.87 | 2.20 | 1.939 |
| 3 | 0.49 | 2,467 | 0.0250 | 0.052 | 3,410 | 0.33 | 0.41 | 0.0250 | 2.50 | 12,168 | 1.35 | 0.87 | 2.22 | 1.963 |
| 4 | 0.49 | 2,443 | 0.0250 | 0.052 | 3,410 | 0.33 | 0.41 | 0.0250 | 2.50 | 12,168 | 1.35 | 0.87 | 2.23 | 1.965 |

## Table 5. Sheet and Shallow Concentrated Flow Computations for Subbasin F

**Sheet Flow**

| Surface Description | | Range |
|---|---|---|
| Manning's roughness coefficient (n) | | 0.13 |
| Flow Length, L | ft | 300 |
| Two-year 24-hour rainfall, p2* | in | 1.4 |
| Land Slope, s | ft/ft | 0.017 |
| Travel Time, Tsheet | hr | 0.57 |

*Precipitation depth, p2
Latitude: 33 27 North
Longitude: 111 38 West
From NOAA Atlas, p2 = 1.4 in

**Upstream Boundary (Flow Depth)**

| Velocity* (ft/s) | Bottom** Slope (ft/ft) | Manning's n | Flow*** Depth (ft) |
|---|---|---|---|
| 2.00 | 0.0132 | 0.05 | 0.45 |

* Average velocity along shallow concentrated flow
** Average bottom slope at the downstream end of the shallow concentrate
*** Flow Depth was computed using the Manning's equation

**Shallow Concentrated Flow**

| Surface description (paved or unpaved) | | Unpaved |
|---|---|---|
| Flow length, L | ft | 1,000 |
| Land slope, s* | ft/ft | 0.015 |
| Average velocity, V ** | ft/s | 2 |
| Travel Time, Tshallow | hr | 0.14 |
| **Total Travel Time*** ** | hr | 0.71 |

* Average land slope along shallow concentrated flow segment
** Use TR-55 (Figure 3.1)
*** Sheet and Shallow Concentrated Flow

## Table 6. Sheet and Shallow Concentrated Flow Computations for Subbasin G

**Sheet Flow**

| Surface Description | | Range |
|---|---|---|
| Manning's roughness coefficient (n) | | 0.13 |
| Flow Length, L | ft | 300 |
| Two-year 24-hour rainfall, p2 | in | 1.4 |
| Land Slope, s | ft/ft | 0.017 |
| Travel Time, Tsheet | hr | 0.57 |

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 2.00 | 0.0137 | 0.05 | 0.44 |

**Shallow Concentrated Flow**

| Surface description (paved or unpaved) | | Unpaved |
|---|---|---|
| Flow length, L | ft | 1,000 |
| Land slope, s | ft/ft | 0.015 |
| Average velocity, V | ft/s | 2 |
| Travel Time, Tshallow | hr | 0.14 |
| **Total Travel Time** | hr | 0.71 |

## Table 7. Sheet and Shallow Concentrated Flow Computations for Subbasin H

**Sheet Flow**

| Surface Description | | Range |
|---|---|---|
| Manning's roughness coefficient (n) | | 0.13 |
| Flow Length, L | ft | 300 |
| Two-year 24-hour rainfall, p2 | in | 1.4 |
| Land Slope, s | ft/ft | 0.033 |
| Travel Time, Tsheet | hr | 0.43 |

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 3.00 | 0.0440 | 0.05 | 0.33 |

**Shallow Concentrated Flow**

| Surface description (paved or unpaved) | | Unpaved |
|---|---|---|
| Flow length, L | ft | 1,340 |
| Land slope, s | ft/ft | 0.034 |
| Average velocity, V | ft/s | 3 |
| Travel Time, Tshallow | hr | 0.12 |
| **Total Travel Time** | hr | 0.56 |

## Table 8. Sheet and Shallow Concentrated Flow Computations for Subbasin I

**Sheet Flow**

| Surface Description | | Range |
|---|---|---|
| Manning's roughness coefficient (n) | | 0.13 |
| Flow Length, L | ft | 300 |
| Two-year 24-hour rainfall, p2 | in | 1.4 |
| Land Slope, s | ft/ft | 0.033 |
| Travel Time, Tsheet | hr | 0.43 |

**Upstream Boundary (Flow Depth)**

| Velocity (ft/s) | Bottom Slope (ft/ft) | Manning's n | Flow Depth (ft) |
|---|---|---|---|
| 2.90 | 0.0245 | 0.05 | 0.49 |

**Shallow Concentrated Flow**

| Surface description (paved or unpaved) | | Unpaved |
|---|---|---|
| Flow length, L | ft | 4,620 |
| Land slope, s | ft/ft | 0.032 |
| Average velocity, V | ft/s | 2.9 |
| Travel Time, Tshallow | hr | 0.44 |
| **Total Travel Time** | hr | 0.87 |

## SPOOK HILL FRS
## Signal Butte Floodway Inflow Hydrograph

### Table 9. Infiltration Parameter Summary

| Subbasin ID | Subbasin Area | Kb | IA (in) | DTHETA | PSIF (in) | Adjusted XKSAT (in/hr) | RTIMP (%) |
|---|---|---|---|---|---|---|---|
| F | 0.15 | 0.057 | 0.30 | 0.25 | 4.5 | 0.37 | 9 |
| G | 0.52 | 0.047 | 0.30 | 0.25 | 5.7 | 0.24 | 15 |
| H | 0.86 | 0.052 | 0.32 | 0.23 | 6.2 | 0.18 | 31 |
| I | 1.32 | 0.050 | 0.30 | 0.25 | 4.5 | 0.39 | 15 |

IA: Initial abstraction
XKSAT: Hydraulic conductivity at natural saturation
PSIF: Wetting front capillary suction
DTHETA: Volumetric soil moisture deficit at the start of rainfall
RTIMP: Effective impervious area
Note: Infiltration parameters were computed using the DDMSW computer program by the FCDMC.

### Table 10. Typical Sections along the Signal Butte Floodway

| Subbasin* ID | Channel Section No. | Channel Type | Channel Reach Station** From | Channel Reach Station** To | Reach Length (ft) | Bottom Slope (ft/ft) | Manning's roughness | Bottom Width (ft) | Top Width (ft) | Side Slope | Depth (ft) | Area ($ft^2$) | Hydraulic Radius (ft) | Discharge*** (cfs) | Velocity (ft/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 1 | Trapezoid | 12+50 | 23+00 | 1,050 | 0.00030 | | | | | | | | | |
| F,G | 2 | | 23+00 | 32+00 | 900 | 0.00030 | 0.025 | 16 | 53.2 | 2:1 | 9.3 | 322 | 5.59 | 1043 | 3.2 |
| G | 3 | | 32+00 | 37+00 | 500 | 0.00030 | 0.025 | 20 | 57.2 | 2:1 | 9.3 | 359 | 5.83 | 1197 | 3.3 |
| G,H | 4 | | 37+00 | 70+00 | 3,300 | 0.00030 | 0.025 | 20 | 58.8 | 2:1 | 9.7 | 382 | 6.03 | 1304 | 3.4 |
| H | 5 | | 70+00 | 90+00 | 2,000 | 0.00030 | 0.025 | 32 | 70.8 | 2:1 | 9.7 | 499 | 6.61 | 1809 | 3.6 |
| H | 6 | | 90+00 | 96+73 | 673 | 0.00027 | 0.025 | 32 | 70.8 | 2:1 | 9.7 | 499 | 6.61 | 1716 | 3.4 |
| | | | | | | | | | | | | | | | |
| H | 7 | Rectangle | 96+73 | 101+53 | 480 | 0.01300 | 0.016 | 10 | 10 | | 6.5 | 65 | 2.83 | 1376 | 21.2 |
| H | 8 | | 101+53 | 105+25 | 372 | 0.01300 | 0.016 | 10 | 10 | | 7.0 | 70 | 2.92 | 1513 | 21.6 |
| H | 9 | | 105+25 | 106+45 | 120 | 0.03330 | 0.016 | 14 | 14 | | 7.3 | 102 | 3.57 | 4049 | 39.6 |
| H | 10 | | 106+45 | 108+40 | 195 | 0.01380 | 0.016 | 14 | 14 | | 7.3 | 102 | 3.57 | 2606 | 25.5 |
| H | 11 | | 108+40 | 109+04 | 64 | 0.01459 | 0.016 | 14 | 14 | | 7.3 | 102 | 3.57 | 2680 | 26.2 |
| H,I | 12 | | 109+04 | 134+06 | 2,502 | 0.01459 | 0.016 | 14 | 14 | | 7.5 | 105 | 3.62 | 2777 | 26.5 |
| I | 13 | | 134+06 | 156+50 | 2,244 | 0.01560 | 0.016 | 14 | 14 | | 7.5 | 105 | 3.62 | 2872 | 27.4 |

*Subbasins within the channel reach limits.
** Reach stations were documented by the SCS (As-built plans, 1983).
*** Channel capacity was computed using Manning's equation.

### Table 11. Hydrologic Routing Parameters

| Typical Section No. | Routing Reaches No. | Velocity* (ft/s) | Length (ft) | NMIN** (min) | NSTPS Compute*** | NSTPS Model**** |
|---|---|---|---|---|---|---|
| 2 | 1 | 3.2 | 560 | 2 | 1.46 | 2 |
| 3 | 2 | 3.3 | 500 | 2 | 1.26 | 2 |
| 4 | 3 | 3.4 | 2030 | 2 | 4.98 | 5 |
| 4 | 4 | 3.4 | 1270 | 2 | 3.11 | 4 |
| 5 | 5 | 3.6 | 2000 | 2 | 4.63 | 5 |
| 6 | 6 | 3.4 | 673 | 2 | 1.65 | 2 |
| 7 | 7 | 21.2 | 480 | 2 | 0.19 | 1 |
| 8 | 8 | 21.6 | 372 | 2 | 0.14 | 1 |
| 9 | 9 | 39.6 | 120 | 2 | 0.03 | 1 |
| 10 | 10 | 25.5 | 195 | 2 | 0.06 | 1 |
| 11 | 11 | 26.2 | 64 | 2 | 0.02 | 1 |
| 12 | 12 | 26.5 | 808 | 2 | 0.25 | 1 |
| 12 | 13 | 26.5 | 1694 | 2 | 0.53 | 1 |
| 13 | 14 | 27.4 | 2244 | 2 | 0.68 | 1 |

* Use Table 10.
** Computational time interval in HEC-1 model.
*** Use the guidelines and procedures in FCDMC Hydrology Manual.
**** Number of steps used in the routing process in the HEC-1 model.

| DMJM | PROJECT: RED MOUNTAIN FREEWAY (POWER RD - UNIVERSITY DR) | JOB NO. | SHEET 1 of 2 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 08/08/01 |
| SUBJECT: Inflow Hydrograph Computations | | CHECKED BY VRM | DATE 8/13/01 |

SIGNAL BUTTE
~~Spook Hill~~ Floodway Channel Capacity (Table 10)

Typical Section No : 1

Channel Type : Trapezoid

Reach Station : (12+50) - (23+00)

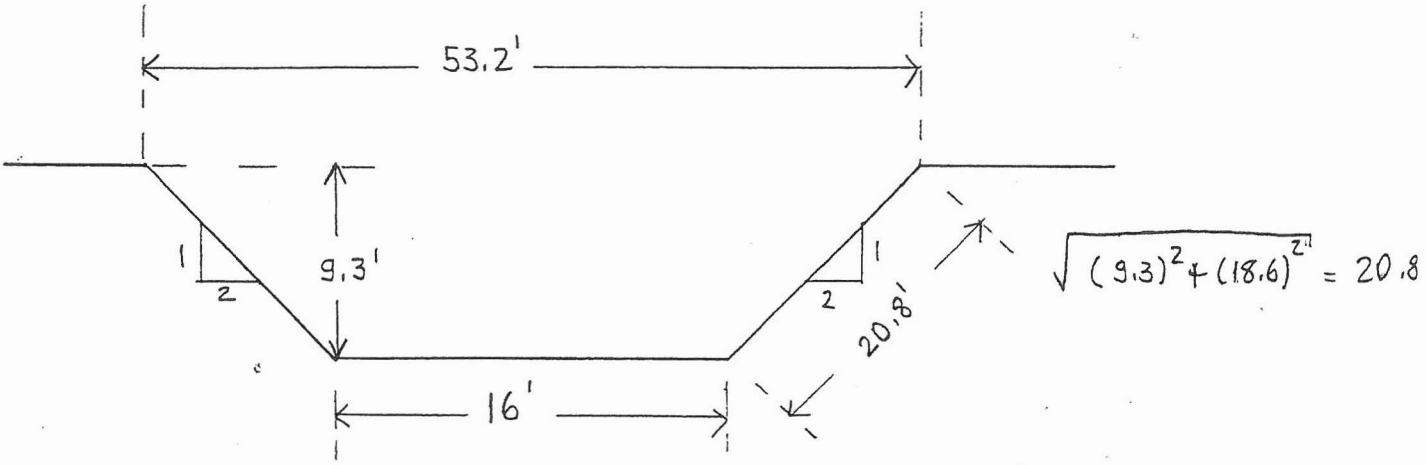
Channel Bottom Slope (S) = 0.0003 ft/ft

Channel Manning's Roughness (n) = 0.025

Bottom Width = 16 ft

Side Slope = 2 : 1

Channel Depth = 9.3 ft




Channel cross-sectional area (A) = $\left(\frac{16 + 53.2}{2}\right)(9.3) = 321.8\ ft^2$

Wetted Perimeter (P) = 16' + (20.8 * 2) = 57.6 ft

Hydraulic Radius (R) = $\frac{A}{P} = \frac{321.8}{57.6} = 5.59$ ft

$Q = \frac{1.486}{n} A R^{2/3} S^{1/2} = \frac{1.486}{0.025}(321.8)(5.59)^{2/3}(0.0003)^{1/2} = 1{,}044$ cfs

Velocity, $V = \frac{Q}{A} = \frac{1{,}044}{321.8} = 3.24$ ft/s

| DMJM | PROJECT: | JOB NO. | SHEET 2 of 2 |
|---|---|---|---|
| | | DESIGNED BY IKT | DATE 08/08/01 |
| SUBJECT: Inflow Hydrograph Computations | | CHECKED BY JRM | DATE 8/13/01 |

## Hydrologic Routing Parameters (Table 11)

Routing Reach No : 1

Velocity, V : 3.2 ft/s (from Table 10)

Reach length, L : 560 ft

Time interval, NMIN : 2 min.

NSTPS : number of steps used in the routing process

$$NSTPS = \frac{L}{(V)(NMIN)(60)}$$

$$= \frac{560}{(3.2)(2)(60)}$$

$$= 1.46$$

Use NSTPS = 2 in the HEC-1 model

# APPENDIX E

# HEC-1 Models

# APPENDIX E

# HEC-1 MODELS

# Appendix E1

## Probable Maximum Precipitation
## General Storm
## (General.dat)

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   26OCT01  TIME  11:45:52   *
*                                       *
*****************************************
```

```
*****************************************
*                                       *
*    U.S. ARMY CORPS OF ENGINEERS       *
*    HYDROLOGIC ENGINEERING CENTER      *
*          609 SECOND STREET            *
*       DAVIS, CALIFORNIA 95616         *
*           (916) 756-1104              *
*                                       *
*****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X               X
XXXXXXX  XXXX     X       XXXXX   X
X     X  X        X               X
X     X  X        X     X         X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: GENERAL.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS THE EXISTING CONDITION OF TWO REPRESENTATIVE SUBBASINS
  7           ID   BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
  8           ID   MANUAL.
  9           ID
 10           ID   HEC-1 MODEL PARAMETERS:
 11           ID       DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 12           ID               WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 13           ID               SUBBASIN LENGTH, SLOPE AND AREA.
 14           ID       HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
 15           ID       PRECIPITATION DEPTH: GENERAL PROBABLE MAXIMUM PRECIPITATION.
 16           ID               COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 17           ID       RAINFALL DURATION: 72 HRS
 18           ID       RAINFALL DISTRIBUTION: USED THE GUIDELINES PROVIDED BY THE ADWR.
 19           ID       LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 20           ID               HYDROLOGY MANUAL (1995).
 21           ID       RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS
 22           ID               RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).
 23           IT     15                    500
 24           IO      3

 25           KK   S-B1
 26           KM   Runoff from Sub-basin B1
 27           BA   4.09
 28           IN    360
 29           PB  19.40
 30           KM   ADWR Guidelines were used to distribute the general PMP
 31           PC   .000    .037    .075    .112    .149    .227    .363    .888    .943    .957
 32           PC   .972    .986   1.000
 33           LG   .290    .250   4.450    .410  11.000
 34           UC   2.15   1.516
 35           UA      0     3.0     5.0     8.0    12.0      20    43.0    75.0    90.0    96.0
 36           UA    100

 37           KK   S-C1
 38           KM   Runoff from Sub-basin C1
 39           BA   2.54
 40           LG   .310    .260   4.350    .460  15.000
 41           UC   1.33    .800
 42           UA      0     5.0    16.0    30.0    65.0      77    84.0    90.0    94.0    97.0
 43           UA    100
 44           ZZ
```

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   26OCT01  TIME  11:45:52  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*           (916) 756-1104             *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: GENERAL.DAT

THIS MODEL REPRESENTS THE EXISTING CONDITION OF TWO REPRESENTATIVE SUBBASINS BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY MANUAL.

HEC-1 MODEL PARAMETERS:

- DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE SUBBASIN LENGTH, SLOPE AND AREA.
- HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
- PRECIPITATION DEPTH: GENERAL PROBABLE MAXIMUM PRECIPITATION. COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.
- RAINFALL DURATION: 72 HRS
- RAINFALL DISTRIBUTION: USED THE GUIDELINES PROVIDED BY THE ADWR.
- LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).
- RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

```
24 IO          OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
                     IPLOT          0  PLOT CONTROL
                     QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT          HYDROGRAPH TIME DATA
                      NMIN         15  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME       0000  STARTING TIME
                        NQ        500  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      6    0  ENDING DATE
                    NDTIME       0445  ENDING TIME
                     ICENT         19  CENTURY MARK

              COMPUTATION INTERVAL     .25 HOURS
                   TOTAL TIME BASE  124.75 HOURS

        ENGLISH UNITS
             DRAINAGE AREA          SQUARE MILES
             PRECIPITATION DEPTH    INCHES
             LENGTH, ELEVATION      FEET
             FLOW                   CUBIC FEET PER SECOND
             STORAGE VOLUME         ACRE-FEET
```

```
          SURFACE AREA          ACRES
          TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


        **************
        *            *
 25 KK  *      S-B1  *
        *            *
        **************
                       Runoff from Sub-basin B1
                       ADWR Guidelines were used to distribute the general PMP

 28 IN        TIME DATA FOR INPUT TIME SERIES
                   JXMIN         360  TIME INTERVAL IN MINUTES
                  JXDATE      1    0  STARTING DATE
                  JXTIME           0  STARTING TIME

          SUBBASIN RUNOFF DATA

 27 BA        SUBBASIN CHARACTERISTICS
                   TAREA        4.09  SUBBASIN AREA

              PRECIPITATION DATA

 30 PB             STORM       19.40  BASIN TOTAL PRECIPITATION

 30 PI          INCREMENTAL PRECIPITATION PATTERN
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                  .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                  .01      .01      .01      .01      .02      .02      .02      .02      .02      .02
                  .02      .02      .02      .02      .02      .02      .02      .02      .02      .02
                  .02      .02      .02      .02      .02      .02      .02      .02      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00
```

```
33 LG          GREEN AND AMPT LOSS RATE
                     STRTL        .29  STARTING LOSS
                       DTH        .25  MOISTURE DEFICIT
                      PSIF       4.45  WETTING FRONT SUCTION
                     XKSAT        .41  HYDRAULIC CONDUCTIVITY
                     RTIMP      11.00  PERCENT IMPERVIOUS AREA

34 UC          CLARK UNITGRAPH
                        TC       2.15  TIME OF CONCENTRATION
                         R       1.52  STORAGE COEFFICIENT

35 UA          ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                     .0      3.0      5.0      8.0     12.0     20.0     43.0     75.0     90.0     96.0
                  100.0

                                                  ***

                                                UNIT HYDROGRAPH PARAMETERS
                                         CLARK   TC=  2.15 HR,       R=  1.52 HR
                                        SNYDER   TP=  1.79 HR,      CP=   .74

                                                 UNIT HYDROGRAPH
                                              38 END-OF-PERIOD ORDINATES
            27.      71.     113.     186.     389.     789.    1088.    1107.    1012.     880.
           746.     632.     536.     454.     385.     326.     277.     235.     199.     169.
           143.     121.     103.      87.      74.      63.      53.      45.      38.      32.
            27.      23.      20.      17.      14.      12.      10.       9.

   ***           ***           ***           ***           ***

                     HYDROGRAPH AT STATION     S-B1

  TOTAL RAINFALL =   19.40, TOTAL LOSS =   10.69, TOTAL EXCESS =    8.71

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR    124.75-HR
   3254.     42.25        (CFS)    2785.        903.        318.        183.
                        (INCHES)   6.331       8.215       8.661       8.668
                         (AC-FT)   1381.       1792.       1889.       1891.

                        CUMULATIVE AREA =    4.09 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


         **************
         *            *
37 KK    *      S-C1  *
         *            *
         **************
                        Runoff from Sub-basin C1

            SUBBASIN RUNOFF DATA

39 BA          SUBBASIN CHARACTERISTICS
                     TAREA        2.54  SUBBASIN AREA
```

PRECIPITATION DATA

30 PB STORM 19.40 BASIN TOTAL PRECIPITATION

30 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .02 | .02 | .02 | .02 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .02 | .02 | .02 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | | |

40 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .31 | STARTING LOSS |
| DTH | .26 | MOISTURE DEFICIT |
| PSIF | 4.35 | WETTING FRONT SUCTION |
| XKSAT | .46 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 15.00 | PERCENT IMPERVIOUS AREA |

41 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | 1.33 | TIME OF CONCENTRATION |
| R | .80 | STORAGE COEFFICIENT |

42 UA ACCUMULATED-AREA VS. TIME, 11 ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .0 | 5.0 | 16.0 | 30.0 | 65.0 | 77.0 | 84.0 | 90.0 | 94.0 | 97.0 |
| 100.0 | | | | | | | | | |

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.33 HR, R= .80 HR

SNYDER TP= .76 HR, CP= .51

UNIT HYDROGRAPH

20 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 130. | 596. | 1027. | 1064. | 924. | 745. | 560. | 408. | 298. | 217. |

159. 116. 84. 62. 45. 33. 24. 17. 13. 9.

*** *** *** *** ***

HYDROGRAPH AT STATION S-C1

TOTAL RAINFALL = 19.40, TOTAL LOSS = 10.50, TOTAL EXCESS = 8.90

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 124.75-HR |
|---|---|---|---|---|---|---|
| 2055. | 42.00 | (CFS) | 1847. | 564. | 202. | 116. |
| | | (INCHES) | 6.761 | 8.260 | 8.859 | 8.864 |
| | | (AC-FT) | 916. | 1119. | 1200. | 1201. |

CUMULATIVE AREA = 2.54 SQ MI

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

| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR | 24-HOUR | 72-HOUR | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|---|---|---|---|---|---|---|---|---|---|
| HYDROGRAPH AT | S-B1 | 3254. | 42.25 | 2785. | 903. | 318. | 4.09 | | |
| HYDROGRAPH AT | S-C1 | 2055. | 42.00 | 1847. | 564. | 202. | 2.54 | | |

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

# Appendix E2

## Probable Maximum Precipitation
## Local Storm
## (Local.dat)

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   25OCT01  TIME  10:31:10  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*           (916) 756-1104             *
*                                      *
****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: LOCAL.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS THE EXISTING CONDITION OF TWO REPRESENTATIVE SUBBASINS
  7           ID   BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY
  8           ID   MANUAL.
  9           ID
 10           ID   HEC-1 MODEL PARAMETERS:
 11           ID        DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 12           ID                WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 13           ID                SUBBASIN LENGTH, SLOPE AND AREA.
 14           ID        HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
 15           ID        PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION.
 16           ID                COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 17           ID        RAINFALL DURATION: 6 HRS
 18           ID        RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.
 19           ID        LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 20           ID                HYDROLOGY MANUAL (1995).
 21           ID        RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS
 22           ID                RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).
 23           IT      2                    500
 24           IO      3

 25           KK    S-B1
 26           KM    Runoff from Sub-basin B1
 27           BA    4.09
 28           IN      15
 29           PB   12.76
 30           KM    HMR 49 (1977) was used to distribute the local PMP
 31           PC    .000    .008    .016    .023    .031    .041    .051    .061    .070    .098
 32           PC    .125    .152    .180    .648    .789    .859    .914    .928    .941    .955
 33           PC    .969    .977    .984    .992   1.000    .000    .000    .000    .000    .000
 34           LG    .290    .250   4.450    .410    11.0
 35           UC   1.860   1.290
 36           UA      0     3.0     5.0     8.0    12.0      20    43.0    75.0    90.0    96.0
 37           UA    100

 38           KK    S-C1
 39           KM    Runoff from Sub-basin C1
 40           BA    2.54
 41           LG    .310    .260   4.350    .460    15.0
 42           UC   1.070   0.626
 43           UA      0     5.0    16.0    30.0    65.0      77    84.0    90.0    94.0    97.0
 44           UA    100
 45           ZZ
```

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   25OCT01  TIME  10:31:10  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*           (916) 756-1104             *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: LOCAL.DAT

THIS MODEL REPRESENTS THE EXISTING CONDITION OF TWO REPRESENTATIVE SUBBASINS BY USING THE PROCEDURES AND GUIDELINES IN HMR 49 AND FCDMC HYDROLOGY MANUAL.

HEC-1 MODEL PARAMETERS:

DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE SUBBASIN LENGTH, SLOPE AND AREA.

HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)

PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION. COMPUTED BY USING THE PROCEDURES AND GUIDELINES IN HMR 49.

RAINFALL DURATION: 6 HRS

RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.

LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

```
24 IO          OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
                     IPLOT          0  PLOT CONTROL
                     QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT          HYDROGRAPH TIME DATA
                      NMIN          2  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME       0000  STARTING TIME
                        NQ        500  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      1    0  ENDING DATE
                    NDTIME       1638  ENDING TIME
                     ICENT         19  CENTURY MARK

              COMPUTATION INTERVAL     .03 HOURS
                   TOTAL TIME BASE   16.63 HOURS

        ENGLISH UNITS
             DRAINAGE AREA         SQUARE MILES
             PRECIPITATION DEPTH   INCHES
             LENGTH, ELEVATION     FEET
             FLOW                  CUBIC FEET PER SECOND
             STORAGE VOLUME        ACRE-FEET
```

```
            SURFACE AREA          ACRES
            TEMPERATURE           DEGREES FAHRENHEIT


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 25 KK    *     S-B1   *
          *            *
          **************
                         Runoff from Sub-basin B1
                         HMR 49 (1977) was used to distribute the local PMP

 28 IN          TIME DATA FOR INPUT TIME SERIES
                      JXMIN          15  TIME INTERVAL IN MINUTES
                     JXDATE      1    0  STARTING DATE
                     JXTIME           0  STARTING TIME

            SUBBASIN RUNOFF DATA

 27 BA          SUBBASIN CHARACTERISTICS
                      TAREA        4.09  SUBBASIN AREA

                PRECIPITATION DATA

 30 PB                STORM       12.76  BASIN TOTAL PRECIPITATION

 30 PI            INCREMENTAL PRECIPITATION PATTERN
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                    .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                    .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                    .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

 34 LG          GREEN AND AMPT LOSS RATE
                      STRTL         .29  STARTING LOSS
                        DTH         .25  MOISTURE DEFICIT
                       PSIF        4.45  WETTING FRONT SUCTION
                      XKSAT         .41  HYDRAULIC CONDUCTIVITY
                      RTIMP       11.00  PERCENT IMPERVIOUS AREA

 35 UC          CLARK UNITGRAPH
                         TC        1.86  TIME OF CONCENTRATION
                          R        1.29  STORAGE COEFFICIENT
```

36 UA ACCUMULATED-AREA VS. TIME, 11 ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .0 | 3.0 | 5.0 | 8.0 | 12.0 | 20.0 | 43.0 | 75.0 | 90.0 | 96.0 |
| 100.0 | | | | | | | | | |

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.86 HR, R= 1.29 HR

SNYDER TP= 1.56 HR, CP= .76

UNIT HYDROGRAPH

240 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5. | 16. | 27. | 37. | 47. | 56. | 62. | 68. | 74. | 79. |
| 84. | 91. | 99. | 107. | 116. | 123. | 132. | 141. | 152. | 163. |
| 173. | 183. | 198. | 220. | 243. | 266. | 288. | 312. | 363. | 437. |
| 509. | 579. | 648. | 723. | 813. | 908. | 1000. | 1091. | 1179. | 1236. |
| 1260. | 1282. | 1304. | 1325. | 1340. | 1338. | 1325. | 1313. | 1301. | 1290. |
| 1276. | 1259. | 1241. | 1224. | 1207. | 1189. | 1165. | 1135. | 1106. | 1078. |
| 1050. | 1024. | 997. | 972. | 947. | 923. | 900. | 877. | 854. | 832. |
| 811. | 791. | 770. | 751. | 732. | 713. | 695. | 677. | 660. | 643. |
| 626. | 610. | 595. | 580. | 565. | 551. | 536. | 523. | 509. | 496. |
| 484. | 471. | 459. | 448. | 436. | 425. | 414. | 404. | 393. | 383. |
| 374. | 364. | 355. | 346. | 337. | 328. | 320. | 312. | 304. | 296. |
| 289. | 281. | 274. | 267. | 260. | 254. | 247. | 241. | 235. | 229. |
| 223. | 217. | 212. | 206. | 201. | 196. | 191. | 186. | 181. | 177. |
| 172. | 168. | 163. | 159. | 155. | 151. | 147. | 144. | 140. | 136. |
| 133. | 130. | 126. | 123. | 120. | 117. | 114. | 111. | 108. | 105. |
| 103. | 100. | 97. | 95. | 93. | 90. | 88. | 86. | 83. | 81. |
| 79. | 77. | 75. | 73. | 71. | 70. | 68. | 66. | 64. | 63. |
| 61. | 60. | 58. | 57. | 55. | 54. | 52. | 51. | 50. | 49. |
| 47. | 46. | 45. | 44. | 43. | 42. | 40. | 39. | 38. | 37. |
| 37. | 36. | 35. | 34. | 33. | 32. | 31. | 30. | 30. | 29. |
| 28. | 27. | 27. | 26. | 25. | 25. | 24. | 24. | 23. | 22. |
| 22. | 21. | 21. | 20. | 20. | 19. | 19. | 18. | 18. | 17. |
| 17. | 16. | 16. | 16. | 15. | 15. | 14. | 14. | 14. | 13. |
| 13. | 13. | 12. | 12. | 12. | 11. | 11. | 11. | 11. | 10. |

*** *** *** *** ***

HYDROGRAPH AT STATION S-B1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.04, TOTAL EXCESS = 9.72

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 11044. | 4.83 | (CFS) | 4137. | 1535. | 1535. | 1535. |
| | | (INCHES) | 9.403 | 9.672 | 9.672 | 9.672 |
| | | (AC-FT) | 2051. | 2110. | 2110. | 2110. |

CUMULATIVE AREA = 4.09 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

**********

* *

```
38 KK     *      S-C1  *
          *            *
          **************
                    Runoff from Sub-basin C1

             SUBBASIN RUNOFF DATA

40 BA          SUBBASIN CHARACTERISTICS
                    TAREA        2.54  SUBBASIN AREA

               PRECIPITATION DATA

30 PB               STORM       12.76  BASIN TOTAL PRECIPITATION

30 PI            INCREMENTAL PRECIPITATION PATTERN
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                    .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                    .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                    .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

41 LG          GREEN AND AMPT LOSS RATE
                    STRTL         .31  STARTING LOSS
                      DTH         .26  MOISTURE DEFICIT
                     PSIF        4.35  WETTING FRONT SUCTION
                    XKSAT         .46  HYDRAULIC CONDUCTIVITY
                    RTIMP       15.00  PERCENT IMPERVIOUS AREA

42 UC          CLARK UNITGRAPH
                       TC        1.07  TIME OF CONCENTRATION
                        R         .63  STORAGE COEFFICIENT

43 UA          ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                      .0       5.0      16.0      30.0      65.0      77.0      84.0      90.0      94.0      97.0
                   100.0

                                                  ***

                                          UNIT HYDROGRAPH PARAMETERS
                                     CLARK   TC=  1.07 HR,       R=   .63 HR
                                    SNYDER   TP=   .55 HR,      CP=   .47

                                          UNIT HYDROGRAPH
                                     114 END-OF-PERIOD ORDINATES
            20.       59.       95.      149.      224.      299.      378.      465.      552.      665.
           856.     1090.     1297.     1402.     1424.     1446.     1447.     1429.     1410.     1390.
          1367.     1343.     1317.     1284.     1250.     1215.     1179.     1141.     1106.     1073.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1041. | 1011. | 971. | 922. | 874. | 829. | 786. | 745. | 707. | 670. |
| 635. | 602. | 571. | 541. | 513. | 487. | 461. | 437. | 415. | 393. |
| 373. | 354. | 335. | 318. | 301. | 286. | 271. | 257. | 244. | 231. |
| 219. | 208. | 197. | 187. | 177. | 168. | 159. | 151. | 143. | 136. |
| 129. | 122. | 116. | 110. | 104. | 98. | 93. | 89. | 84. | 80. |
| 75. | 72. | 68. | 64. | 61. | 58. | 55. | 52. | 49. | 47. |
| 44. | 42. | 40. | 38. | 36. | 34. | 32. | 31. | 29. | 27. |
| 26. | 25. | 23. | 22. | 21. | 20. | 19. | 18. | 17. | 16. |
| 15. | 14. | 14. | 13. | | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-C1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.10, TOTAL EXCESS = 9.66

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 10683. | 3.87 | (CFS) | 2616. | 947. | 947. | 947. |
| | | (INCHES) | 9.575 | 9.613 | 9.613 | 9.613 |
| | | (AC-FT) | 1297. | 1302. | 1302. | 1302. |

CUMULATIVE AREA = 2.54 SQ MI

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

| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR | 24-HOUR | 72-HOUR | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|---|---|---|---|---|---|---|---|---|---|
| HYDROGRAPH AT | S-B1 | 11044. | 4.83 | 4137. | 1535. | 1535. | 4.09 | | |
| HYDROGRAPH AT | S-C1 | 10683. | 3.87 | 2616. | 947. | 947. | 2.54 | | |

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

# Appendix E3

## Recommended Existing Hydrologic Conditions Model
## Full PMF
## (Spkfpmf.dat)

```
*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*              JUN   1998               *
*           VERSION 4.1                 *
*                                       *
*  RUN DATE   25OCT01  TIME  11:12:30   *
*                                       *
*****************************************
```

```
*****************************************
*                                       *
*    U.S. ARMY CORPS OF ENGINEERS       *
*    HYDROLOGIC ENGINEERING CENTER      *
*          609 SECOND STREET            *
*       DAVIS, CALIFORNIA 95616         *
*           (916) 756-1104              *
*                                       *
*****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: SPKFPMF.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS EXISTING CONDITIONS FOR THE CONTRIBUTING WATERSHED
  7           ID   TO THE SPOOK HILL FRS AND THE UNCONTROLLED DRAINAGE AREA BETWEEN THE PASS
  8           ID   MOUNTAIN DIVERSION AND THE SIGNAL BUTTE FLOODWAY. THE PROCEDURES AND
  9           ID   GUIDELINES IN HMR 49 AND THE FCDMC HYDROLOGY MANUAL WERE USED.
 10           ID
 11           ID   HEC-1 MODEL PARAMETERS:
 12           ID        DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 13           ID                WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 14           ID                SUBBASIN LENGTH, SLOPE AND AREA.
 15           ID        HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)
 16           ID        INFLOW HYDROGRAPH: THE MAXIMUM 100-YEAR, 24-HOUR STORM SIGNAL BUTTE FRS
 17           ID                           PRINCIPAL SPILLWAY OUTFLOW (157 cfs) WAS ASSUMED
 18           ID                           FOR THE UPPER CONTRIBUTING WATERSHED.
 19           ID        PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION COMPUTED
 20           ID                             USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 21           ID        RAINFALL DURATION: 6 HRS
 22           ID        RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.
 23           ID        LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 24           ID                HYDROLOGY MANUAL (1995).
 25           ID        RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH
 26           ID        CHANNEL ROUTING: NORMAL DEPTH CHANNEL ROUTING
 27           ID        RESERVOIR ROUTING: MODIFIED PULS RESERVOIR ROUTING
              *DIAGRAM
 28           IT       2                    500
 29           IO       3

 30           KK    S-IN
 31           KM   SIGNAL BUTTE FRS INFLOW
 32           BA   0.001
 33           QI     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 34           QI     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 35           QI     0.0     0.0     0.0     0.0   157.0   157.0   157.0   157.0   157.0   157.0
 36           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 37           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 38           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 39           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 40           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 41           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 42           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 43           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 44           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 45           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 46           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 47           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 48           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 49           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 50           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 51           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 52           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
 53           QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  54          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  55          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  56          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  57          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  58          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  59          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  60          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  61          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  62          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  63          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  64          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  65          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  66          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  67          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  68          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  69          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  70          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  71          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  72          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  73          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  74          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  75          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  76          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  77          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  78          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  79          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  80          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  81          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0
  82          QI   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0   157.0

  83          KK     S-F
  84          KM    Runoff from Sub-basin F
  85          BA    0.15
  86          IN      15
  87          PB   12.76
  88          KM    HMR 49 (1977) was used to distribute the local PMP
  89          PC    .000    .008    .016    .023    .031    .041    .051    .061    .070    .098
  90          PC    .125    .152    .180    .648    .789    .859    .914    .928    .941    .955
  91          PC    .969    .977    .984    .992   1.000
  92          LG    .300    .250   4.500    .370     9.0
  93          UC   1.040   0.908

  94          KK    C-C1
  95          KM    Combine S-IN and S-F
  96          HC       2

  97          KK    DIVF
  98          KM    Divert flows in excess of the Signal Butte Floodway capacity
  99          DT    DV-F
 100          DI       0    1043    1044
 101          DQ       0       0       1
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 102          KK     R-F
 103          KM    Route DIVF to G
 104          RS       7    FLOW      -1
 105          RC    .035    .025    .035    3090  0.0003
 106          RX       0       1       2    21.4    41.4    60.8      61      62
 107          RY     9.7     9.7     9.7       0       0     9.7     9.7     9.7

 108          KK     S-G
 109          KM    Runoff from Sub-basin G
 110          BA    0.52
 111          LG    .300    .250   5.700    .240    15.0
 112          UC   1.030    .456

 113          KK    C-C2
 114          KM    Combine R-F and S-G
 115          HC       2

 116          KK    DIVG
 117          KM    Divert flows in excess of the Signal Butte Floodway capacity
 118          DT    DV-G
 119          DI       0    1304    1305
 120          DQ       0       0       1

 121          KK   R-G-1
 122          KM    Route DIVG to G1 - EARTHEN
 123          RS      14    FLOW      -1
 124          RC    .035    .025    .035    3943 0.00029
 125          RX       0       1       2    21.4    53.4    72.8      73      74
 126          RY     9.7     9.7     9.7       0       0     9.7     9.7     9.7

 127          KK   R-G-2
 128          KM    Route G1 to H - CONCRETE
 129          RS       2    FLOW      -1
 130          RC    .016    .016    .016    2039 0.01495
 131          RX       0       1       2     2.1    16.1    16.2      17      18
 132          RY     7.5     7.5     7.5       0       0     7.5     7.5     7.5

 133          KK     S-H
 134          KM    Runoff from Sub-basin H
 135          BA    0.86
 136          LG    .320    .250   4.400    .410    14.0
 137          UC   2.030   1.977

 138          KK    C-C3
 139          KM    Combine R-G-2 and S-H
 140          HC       2

 141          KK    DIVH
 142          KM    Divert flows in excess of the Signal Butte Floodway capacity
 143          DT    DV-H
 144          DI       0    2777    2778
 145          DQ       0       0       1
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

146           KK     R-H
147           KM    Route DIVH to S-I
148           RS       2    FLOW      -1
149           RC    .016    .016    .016    3938  0.0152
150           RX       0       1       2     2.1    16.1    16.2      17      18
151           RY     7.5     7.5     7.5       0       0     7.5     7.5     7.5

152           KK     S-I
153           KM    Runoff from Sub-basin I
154           BA    1.32
155           LG    .300    .250   4.500    .390    15.0
156           UC   2.010   1.752

157           KK    C-C4
158           KM    Combine R-H and S-I
159           HC       2

160           KK    DIVI
161           KM    Divert flows in excess of the Signal Butte Floodway capacity
162           DT    DV-I
163           DI       0    2872    2873
164           DQ       0       0       1

165           KK    S-A1
166           KM    Runoff from Sub-basin A1
167           BA    0.96
168           LG    .300    .260   4.250    .470    16.0
169           UC   1.220   0.925

170           KK    C-C5
171           KM    Combine S-A1 and DIVI
172           HC       2

173           KK    S-B1
174           KM    Runoff from Sub-basin B1
175           BA    4.09
176           LG    .290    .250   4.450    .410    11.0
177           UC   1.860   1.290
178           UA       0     3.0     5.0     8.0    12.0      20    43.0    75.0    90.0    96.0
179           UA     100

180           KK    C-C6
181           KM    Combine C-C5 and S-B1
182           HC       2

183           KK    S-B2
184           KM    Runoff from Sub-basin B2
185           BA    1.36
186           LG    .310    .260   4.350    .460    15.0
187           UC   1.870   1.641
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 188          KK    C-C7
 189          KM    Combine C-C6 and S-B2
 190          HC       2

 191          KK    S-C1
 192          KM    Runoff from Sub-basin C1
 193          BA    2.54
 194          LG    .310    .260   4.350    .460    15.0
 195          UC   1.070   0.626
 196          UA       0     5.0    16.0    30.0    65.0      77    84.0    90.0    94.0    97.0
 197          UA     100

 198          KK    C-C8
 199          KM    Combine C-C7 and S-C1
 200          HC       2

 201          KK    S-D1
 202          KM    Runoff from Sub-basin D1
 203          BA    1.15
 204          LG    .300    .270   3.640    .670    17.0
 205          UC    .900    .649

 206          KK    C-C9
 207          KM    Combine C-C8 and S-D1
 208          HC       2

 209          KK     RES
 210          KM    Spook Hill Reservoir Routing
 211          KM    See DMJM+HARRIS Technical Report No. 1 for supporting details
 212          KM    behind rating curves.
 213          KM
 214          KM    NGVD 29 elevations used in the computations.
 215          KM
 216          KM    Sediment Storage Volume Below Principle Spillway = 271 Ac-Ft (Elev=1577.5')
 217          RS       1    STOR       0
 218          SV       0     287     346   474.9     693    1120    1631    1919    2231    2927
 219          SV    3722    4158
 220          SQ       0       0     250     500     750     990    2860    4750    7000   12750
 221          SQ   19240   23050
 222          SE  1575.1  1577.5    1578  1578.8    1580    1582    1584    1585    1586    1588
 223          SE    1590    1591
 224          ZZ
```

SCHEMATIC DIAGRAM OF STREAM NETWORK

```
INPUT
 LINE     (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

  NO.     (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

   30       S-IN
               .
               .
   83          .         S-F
               .           .
               .           .
   94       C-C1............
               .
               .
   99          .------->    DV-F
   97       DIVF
               V
               V
  102        R-F
               .
               .
  108          .         S-G
               .           .
               .           .
  113       C-C2............
               .
               .
  118          .------->    DV-G
  116       DIVG
               V
               V
  121      R-G-1
               V
               V
  127      R-G-2
               .
               .
  133          .         S-H
               .           .
               .           .
  138       C-C3............
               .
               .
  143          .------->    DV-H
  141       DIVH
               V
               V
  146        R-H
               .
               .
  152          .         S-I
               .           .
               .           .
  157       C-C4............
               .
               .
  162          .------->    DV-I
  160       DIVI
```

```
              .
              .
165           .        S-A1
              .          .
              .          .
170        C-C5............
              .
              .
173           .        S-B1
              .          .
              .          .
180        C-C6............
              .
              .
183           .        S-B2
              .          .
              .          .
188        C-C7............
              .
              .
191           .        S-C1
              .          .
              .          .
198        C-C8............
              .
              .
201           .        S-D1
              .          .
              .          .
206        C-C9............
              V
              V
209         RES
```

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   25OCT01  TIME  11:12:30  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*       DAVIS, CALIFORNIA 95616        *
*           (916) 756-1104             *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: SPKFPMF.DAT

THIS MODEL REPRESENTS EXISTING CONDITIONS FOR THE CONTRIBUTING WATERSHED TO THE SPOOK HILL FRS AND THE UNCONTROLLED DRAINAGE AREA BETWEEN THE PASS MOUNTAIN DIVERSION AND THE SIGNAL BUTTE FLOODWAY. THE PROCEDURES AND GUIDELINES IN HMR 49 AND THE FCDMC HYDROLOGY MANUAL WERE USED.

HEC-1 MODEL PARAMETERS:

DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE SUBBASIN LENGTH, SLOPE AND AREA.

HYDROGRAPH: PROBABLE MAXIMUM FLOOD (PMF)

INFLOW HYDROGRAPH: THE MAXIMUM 100-YEAR, 24-HOUR STORM SIGNAL BUTTE FRS PRINCIPAL SPILLWAY OUTFLOW (157 cfs) WAS ASSUMED FOR THE UPPER CONTRIBUTING WATERSHED.

PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION COMPUTED USING THE PROCEDURES AND GUIDELINES IN HMR 49.

RAINFALL DURATION: 6 HRS

RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.

LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH

CHANNEL ROUTING: NORMAL DEPTH CHANNEL ROUTING

RESERVOIR ROUTING: MODIFIED PULS RESERVOIR ROUTING

```
29 IO          OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
                     IPLOT          0  PLOT CONTROL
                     QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT          HYDROGRAPH TIME DATA
                      NMIN          2  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME       0000  STARTING TIME
                        NQ        500  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      1    0  ENDING DATE
                    NDTIME       1638  ENDING TIME
                     ICENT         19  CENTURY MARK

              COMPUTATION INTERVAL     .03 HOURS
                   TOTAL TIME BASE   16.63 HOURS

        ENGLISH UNITS
```

```
DRAINAGE AREA          SQUARE MILES
PRECIPITATION DEPTH    INCHES
LENGTH, ELEVATION      FEET
FLOW                   CUBIC FEET PER SECOND
STORAGE VOLUME         ACRE-FEET
SURFACE AREA           ACRES
TEMPERATURE            DEGREES FAHRENHEIT
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
 30 KK        *      S-IN  *
              *            *
              **************
                             SIGNAL BUTTE FRS INFLOW

                 SUBBASIN RUNOFF DATA

 32 BA             SUBBASIN CHARACTERISTICS
                         TAREA          .00  SUBBASIN AREA

                                                          ***

     ***              ***              ***              ***              ***

                          HYDROGRAPH AT STATION     S-IN

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
     157.       .80        (CFS)     157.        150.        150.        150.
                         (INCHES)  1459.712    3856.072    3856.072    3856.072
                          (AC-FT)     78.        206.        206.        206.

                          CUMULATIVE AREA =     .00 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
 83 KK        *       S-F  *
              *            *
              **************
                             Runoff from Sub-basin F
                             HMR 49 (1977) was used to distribute the local PMP

 86 IN             TIME DATA FOR INPUT TIME SERIES
                        JXMIN          15  TIME INTERVAL IN MINUTES
                       JXDATE      1    0  STARTING DATE
                       JXTIME           0  STARTING TIME

                 SUBBASIN RUNOFF DATA
```

85 BA SUBBASIN CHARACTERISTICS

TAREA .15 SUBBASIN AREA

PRECIPITATION DATA

88 PB STORM 12.76 BASIN TOTAL PRECIPITATION

88 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

92 LG GREEN AND AMPT LOSS RATE

STRTL .30 STARTING LOSS

DTH .25 MOISTURE DEFICIT

PSIF 4.50 WETTING FRONT SUCTION

XKSAT .37 HYDRAULIC CONDUCTIVITY

RTIMP 9.00 PERCENT IMPERVIOUS AREA

93 UC CLARK UNITGRAPH

TC 1.04 TIME OF CONCENTRATION

R .91 STORAGE COEFFICIENT

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.04 HR, R= .91 HR

SNYDER TP= .96 HR, CP= .62

UNIT HYDROGRAPH

161 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 2. | 3. | 5. | 8. | 10. | 13. | 16. | 19. | 22. |
| 25. | 29. | 32. | 35. | 39. | 42. | 46. | 49. | 52. | 54. |
| 57. | 59. | 61. | 62. | 63. | 64. | 65. | 65. | 65. | 64. |
| 63. | 62. | 60. | 57. | 55. | 53. | 51. | 50. | 48. | 46. |
| 44. | 43. | 41. | 40. | 38. | 37. | 36. | 34. | 33. | 32. |
| 31. | 30. | 29. | 28. | 27. | 26. | 25. | 24. | 23. | 22. |
| 21. | 21. | 20. | 19. | 18. | 18. | 17. | 16. | 16. | 15. |
| 15. | 14. | 14. | 13. | 13. | 12. | 12. | 11. | 11. | 11. |
| 10. | 10. | 9. | 9. | 9. | 9. | 8. | 8. | 8. | 7. |
| 7. | 7. | 7. | 6. | 6. | 6. | 6. | 5. | 5. | 5. |
| 5. | 5. | 5. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 2. |

```
          2.       2.       2.       2.       2.       2.       2.       2.       2.       2.
          2.       2.       2.       1.       1.       1.       1.       1.       1.       1.
          1.       1.       1.       1.       1.       1.       1.       1.       1.       1.
          1.       1.       1.       1.       1.       1.       1.       1.       1.       1.
          1.

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION      S-F

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    2.96, TOTAL EXCESS =    9.80

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   529.       4.13       (CFS)     156.         57.         57.         57.
                       (INCHES)   9.679       9.747       9.747       9.747
                        (AC-FT)    77.         78.         78.         78.

                     CUMULATIVE AREA =     .15 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


         **************
         *            *
 94 KK   *      C-C1  *
         *            *
         **************
                    Combine S-IN and S-F

 96 HC        HYDROGRAPH COMBINATION
                    ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                    ***

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION     C-C1

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   686.       4.13       (CFS)     313.        206.        206.        206.
                       (INCHES)  19.282      35.219      35.219      35.219
                        (AC-FT)    155.        284.        284.        284.

                     CUMULATIVE AREA =     .15 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


         **************
         *            *
 97 KK   *      DIVF  *
         *            *
```

```
**************
                    Divert flows in excess of the Signal Butte Floodway capacity

DT          DIVERSION
                 ISTAD        DV-F  DIVERSION HYDROGRAPH IDENTIFICATION

DI             INFLOW         .00   1043.00   1044.00

DQ      DIVERTED FLOW         .00       .00      1.00

                                                          ***

 ***            ***            ***            ***            ***

                  DIVERSION HYDROGRAPH     DV-F

PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
    0.        .00        (CFS)      0.          0.          0.          0.
                       (INCHES)    .000        .000        .000        .000
                        (AC-FT)      0.          0.          0.          0.

                  CUMULATIVE AREA =     .15 SQ MI


 ***            ***            ***            ***            ***

                  HYDROGRAPH AT STATION     DIVF

PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   686.       4.13       (CFS)    313.        206.        206.        206.
                       (INCHES)  19.282      35.219      35.219      35.219
                        (AC-FT)    155.        284.        284.        284.

                  CUMULATIVE AREA =     .15 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
102 KK    *      R-F   *
          *            *
          **************
                    Route DIVF to G

            HYDROGRAPH ROUTING DATA

104 RS        STORAGE ROUTING
                   NSTPS          7  NUMBER OF SUBREACHES
                    ITYP       FLOW  TYPE OF INITIAL CONDITION
                  RSVRIC      -1.00  INITIAL CONDITION
                       X        .00 WORKING R AND D COEFFICIENT

105 RC        NORMAL DEPTH CHANNEL
                     ANL       .035  LEFT OVERBANK N-VALUE
```

| | | |
|---|---|---|
| ANCH | .025 | MAIN CHANNEL N-VALUE |
| ANR | .035 | RIGHT OVERBANK N-VALUE |
| RLNTH | 3090. | REACH LENGTH |
| SEL | .0003 | ENERGY SLOPE |
| ELMAX | .0 | MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION |

CROSS-SECTION DATA

| | | --- LEFT OVERBANK --- | | | + ------ MAIN CHANNEL ------- | | + --- RIGHT OVERBANK --- | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 RY | ELEVATION | 9.70 | 9.70 | 9.70 | .00 | .00 | 9.70 | 9.70 | 9.70 |
| 106 RX | DISTANCE | .00 | 1.00 | 2.00 | 21.40 | 41.40 | 60.80 | 61.00 | 62.00 |

***

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | .00 | .76 | 1.60 | 2.51 | 3.49 | 4.55 | 5.68 | 6.88 | 8.16 | 9.51 |
| OUTFLOW | .00 | 6.81 | 21.92 | 43.78 | 71.98 | 106.41 | 147.05 | 194.01 | 247.39 | 307.35 |
| ELEVATION | .00 | .51 | 1.02 | 1.53 | 2.04 | 2.55 | 3.06 | 3.57 | 4.08 | 4.59 |
| STORAGE | 10.94 | 12.44 | 14.02 | 15.67 | 17.39 | 19.18 | 21.06 | 23.00 | 25.02 | 27.11 |
| OUTFLOW | 374.05 | 447.65 | 528.33 | 616.29 | 711.70 | 814.74 | 925.61 | 1044.49 | 1171.57 | 1307.03 |
| ELEVATION | 5.11 | 5.62 | 6.13 | 6.64 | 7.15 | 7.66 | 8.17 | 8.68 | 9.19 | 9.70 |

*** *** *** *** ***

HYDROGRAPH AT STATION R-F

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 679. | 4.37 | (CFS) | 313. | 202. | 202. | 202. |
| | | (INCHES) | 19.280 | 34.482 | 34.482 | 34.482 |
| | | (AC-FT) | 155. | 278. | 278. | 278. |

| PEAK STORAGE (AC-FT) | TIME (HR) | MAXIMUM AVERAGE STORAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 2. | 4.33 | 1. | 1. | 1. | 1. |

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 6.97 | 4.37 | 4.48 | 3.42 | 3.42 | 3.42 |

CUMULATIVE AREA = .15 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
108 KK        *      S-G   *
              *            *
              **************
```

Runoff from Sub-basin G

SUBBASIN RUNOFF DATA

110 BA SUBBASIN CHARACTERISTICS

```
                TAREA          .52  SUBBASIN AREA

            PRECIPITATION DATA

88 PB           STORM        12.76  BASIN TOTAL PRECIPITATION

88 PI         INCREMENTAL PRECIPITATION PATTERN
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

111 LG        GREEN AND AMPT LOSS RATE
                STRTL          .30  STARTING LOSS
                  DTH          .25  MOISTURE DEFICIT
                 PSIF         5.70  WETTING FRONT SUCTION
                XKSAT          .24  HYDRAULIC CONDUCTIVITY
                RTIMP        15.00  PERCENT IMPERVIOUS AREA

112 UC        CLARK UNITGRAPH
                   TC         1.03  TIME OF CONCENTRATION
                    R          .46  STORAGE COEFFICIENT

            SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                  ***

                                          UNIT HYDROGRAPH PARAMETERS
                                   CLARK   TC=  1.03 HR,       R=   .46 HR
                                  SNYDER   TP=   .84 HR,      CP=   .77

                                          UNIT HYDROGRAPH
                                     90 END-OF-PERIOD ORDINATES
            3.      11.      22.      36.      51.      67.      84.     101.     119.     137.
          155.     173.     191.     209.     227.     245.     261.     276.     288.     298.
          306.     312.     316.     318.     319.     317.     314.     310.     303.     293.
          280.     263.     244.     227.     211.     196.     182.     170.     158.     146.
          136.     127.     118.     109.     102.      94.      88.      82.      76.      70.
           66.      61.      57.      53.      49.      45.      42.      39.      36.      34.
           32.      29.      27.      25.      24.      22.      20.      19.      18.      16.
           15.      14.      13.      12.      11.      11.      10.       9.       8.       8.
            7.       7.       6.       6.       5.       5.       5.       4.       4.       4.

***          ***          ***          ***          ***

                HYDROGRAPH AT STATION      S-G
```

```
   TOTAL RAINFALL =   12.76, TOTAL LOSS =    2.37, TOTAL EXCESS =   10.39

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   2580.       4.03       (CFS)     576.        208.        208.        208.
                        (INCHES)   10.305      10.334      10.334      10.334
                         (AC-FT)    286.        287.        287.        287.

                         CUMULATIVE AREA =     .52 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


           **************
           *            *
 113 KK    *      C-C2  *
           *            *
           **************
                          Combine R-F and S-G

 115 HC          HYDROGRAPH COMBINATION
                      ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION     C-C2

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   3161.       4.07       (CFS)     887.        410.        410.        410.
                        (INCHES)   12.285      15.768      15.768      15.768
                         (AC-FT)    440.        564.        564.        564.

                         CUMULATIVE AREA =     .67 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


           **************
           *            *
 116 KK    *      DIVG  *
           *            *
           **************
                          Divert flows in excess of the Signal Butte Floodway capacity

    DT          DIVERSION
                      ISTAD        DV-G  DIVERSION HYDROGRAPH IDENTIFICATION

    DI             INFLOW         .00   1304.00   1305.00

    DQ      DIVERTED FLOW         .00       .00      1.00
```

```
                                                                  ***

    ***            ***            ***            ***            ***

                      DIVERSION HYDROGRAPH     DV-G

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
    1857.      4.07       (CFS)     259.         94.         94.         94.
                        (INCHES)   3.594       3.594       3.594       3.594
                         (AC-FT)    129.        129.        129.        129.

                       CUMULATIVE AREA =     .67 SQ MI


    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION     DIVG

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
    1304.      3.47       (CFS)     627.        317.        317.        317.
                        (INCHES)   8.691      12.174      12.174      12.174
                         (AC-FT)    311.        436.        436.        436.

                       CUMULATIVE AREA =     .67 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
121 KK    *     R-G-1  *
          *            *
          **************
                          Route DIVG to G1 - EARTHEN

             HYDROGRAPH ROUTING DATA

123 RS          STORAGE ROUTING
                      NSTPS          14  NUMBER OF SUBREACHES
                       ITYP        FLOW  TYPE OF INITIAL CONDITION
                     RSVRIC       -1.00  INITIAL CONDITION
                          X         .00 WORKING R AND D COEFFICIENT

124 RC          NORMAL DEPTH CHANNEL
                        ANL        .035  LEFT OVERBANK N-VALUE
                       ANCH        .025  MAIN CHANNEL N-VALUE
                        ANR        .035  RIGHT OVERBANK N-VALUE
                      RLNTH       3943.  REACH LENGTH
                        SEL      .0003  ENERGY SLOPE
                      ELMAX          .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                      CROSS-SECTION DATA
                          --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
126 RY        ELEVATION      9.70      9.70      9.70       .00       .00      9.70      9.70      9.70
```

```
125 RX        DISTANCE        .00      1.00      2.00     21.40     53.40     72.80     73.00     74.00

                                                   ***

                                        COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

          STORAGE        .00      1.53      3.15      4.86      6.67      8.57     10.57     12.66     14.85     17.13
          OUTFLOW        .00     10.66     34.11     67.64    110.32    161.70    221.56    289.79    366.37    451.32
        ELEVATION        .00       .51      1.02      1.53      2.04      2.55      3.06      3.57      4.08      4.59

          STORAGE      19.51     21.98     24.54     27.20     29.95     32.80     35.74     38.78     41.91     45.13
          OUTFLOW     544.70    646.60    757.12    876.38   1004.50   1141.63   1287.91   1443.47   1608.47   1783.06
        ELEVATION       5.11      5.62      6.13      6.64      7.15      7.66      8.17      8.68      9.19      9.70


*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN     1443. TO     1783.
                THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
                THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION    R-G-1

 PEAK FLOW     TIME                        MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   1304.       3.93       (CFS)     627.        311.        311.        311.
                        (INCHES)   8.691      11.940      11.940      11.940
                        (AC-FT)    311.        427.        427.        427.

PEAK STORAGE   TIME                        MAXIMUM AVERAGE STORAGE
  (AC-FT)      (HR)                 6-HR       24-HR       72-HR     16.63-HR
      3.       3.87                   1.          1.          1.          1.

 PEAK STAGE    TIME                        MAXIMUM AVERAGE STAGE
   (FEET)      (HR)                 6-HR       24-HR       72-HR     16.63-HR
    8.22       3.97                 5.12        3.19        3.19        3.19

                        CUMULATIVE AREA =     .67 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
127 KK    *    R-G-2   *
          *            *
          **************
                        Route G1 to H - CONCRETE

             HYDROGRAPH ROUTING DATA

129 RS          STORAGE ROUTING
                      NSTPS          2  NUMBER OF SUBREACHES
                       ITYP       FLOW  TYPE OF INITIAL CONDITION
                     RSVRIC      -1.00  INITIAL CONDITION
                          X        .00 WORKING R AND D COEFFICIENT
```

```
130 RC          NORMAL DEPTH CHANNEL
                       ANL        .016  LEFT OVERBANK N-VALUE
                      ANCH        .016  MAIN CHANNEL N-VALUE
                       ANR        .016  RIGHT OVERBANK N-VALUE
                     RLNTH       2039.  REACH LENGTH
                       SEL       .0149  ENERGY SLOPE
                     ELMAX          .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                   CROSS-SECTION DATA
                         --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
132 RY       ELEVATION    7.50    7.50    7.50     .00     .00    7.50    7.50    7.50
131 RX       DISTANCE      .00    1.00    2.00    2.10   16.10   16.20   17.00   18.00

                                                   ***

                                   COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

          STORAGE      .00     .26     .52     .78    1.04    1.30    1.56    1.82    2.08    2.34
          OUTFLOW      .00   32.66  100.23  190.75  298.76  420.81  554.45  697.84  849.58 1008.54
        ELEVATION      .00     .39     .79    1.18    1.58    1.97    2.37    2.76    3.16    3.55

          STORAGE     2.60    2.86    3.12    3.38    3.64    3.90    4.16    4.43    4.69    4.95
          OUTFLOW  1173.80 1344.61 1520.34 1700.48 1884.57 2072.23 2263.13 2456.99 2653.56 2852.61
        ELEVATION     3.95    4.34    4.74    5.13    5.53    5.92    6.32    6.71    7.11    7.50


*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN      191. TO     2853.
                THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
                THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION    R-G-2

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   1304.       4.00       (CFS)     627.        310.        310.        310.
                        (INCHES)   8.691      11.921      11.921      11.921
                         (AC-FT)    311.        427.        427.        427.

PEAK STORAGE   TIME                          MAXIMUM AVERAGE STORAGE
  (AC-FT)      (HR)                 6-HR       24-HR       72-HR     16.63-HR
      1.       3.87                   1.          0.          0.          0.

 PEAK STAGE    TIME                          MAXIMUM AVERAGE STAGE
   (FEET)      (HR)                 6-HR       24-HR       72-HR     16.63-HR
    4.25       4.00                 2.44        1.44        1.44        1.44

                        CUMULATIVE AREA =     .67 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
133 KK    *      S-H   *
          *            *
```

```
**************
                Runoff from Sub-basin H

          SUBBASIN RUNOFF DATA

135 BA      SUBBASIN CHARACTERISTICS
                TAREA          .86  SUBBASIN AREA

            PRECIPITATION DATA

 88 PB          STORM        12.76  BASIN TOTAL PRECIPITATION

 88 PI        INCREMENTAL PRECIPITATION PATTERN
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

136 LG      GREEN AND AMPT LOSS RATE
                STRTL          .32  STARTING LOSS
                  DTH          .25  MOISTURE DEFICIT
                 PSIF         4.40  WETTING FRONT SUCTION
                XKSAT          .41  HYDRAULIC CONDUCTIVITY
                RTIMP        14.00  PERCENT IMPERVIOUS AREA

137 UC      CLARK UNITGRAPH
                  TC         2.03  TIME OF CONCENTRATION
                   R         1.98  STORAGE COEFFICIENT

            SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                          ***

                                   UNIT HYDROGRAPH PARAMETERS
                             CLARK   TC=  2.03 HR,       R=  1.98 HR
                            SNYDER   TP=  1.91 HR,      CP=   .59

                                    UNIT HYDROGRAPH
                              300 END-OF-PERIOD ORDINATES
                                     VOLUME =  .99
          0.       2.       3.       5.       8.      10.      13.      16.      20.      23.
         27.      30.      34.      38.      42.      46.      50.      55.      59.      63.
         68.      72.      77.      82.      86.      91.      96.     101.     106.     111.
        116.     120.     125.     130.     134.     138.     142.     146.     149.     152.
        155.     158.     161.     164.     166.     168.     170.     172.     174.     175.
        176.     177.     178.     178.     179.     179.     178.     178.     177.     176.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 174. | 171. | 169. | 166. | 163. | 160. | 158. | 155. | 152. | 150. |
| 147. | 145. | 142. | 140. | 138. | 135. | 133. | 131. | 129. | 127. |
| 124. | 122. | 120. | 118. | 116. | 114. | 112. | 111. | 109. | 107. |
| 105. | 103. | 102. | 100. | 98. | 97. | 95. | 93. | 92. | 90. |
| 89. | 87. | 86. | 84. | 83. | 82. | 80. | 79. | 78. | 76. |
| 75. | 74. | 73. | 71. | 70. | 69. | 68. | 67. | 66. | 64. |
| 63. | 62. | 61. | 60. | 59. | 58. | 57. | 56. | 55. | 54. |
| 54. | 53. | 52. | 51. | 50. | 49. | 48. | 48. | 47. | 46. |
| 45. | 44. | 44. | 43. | 42. | 42. | 41. | 40. | 40. | 39. |
| 38. | 38. | 37. | 36. | 36. | 35. | 35. | 34. | 33. | 33. |
| 32. | 32. | 31. | 31. | 30. | 30. | 29. | 29. | 28. | 28. |
| 27. | 27. | 26. | 26. | 25. | 25. | 25. | 24. | 24. | 23. |
| 23. | 23. | 22. | 22. | 22. | 21. | 21. | 20. | 20. | 20. |
| 19. | 19. | 19. | 19. | 18. | 18. | 18. | 17. | 17. | 17. |
| 16. | 16. | 16. | 16. | 15. | 15. | 15. | 15. | 14. | 14. |
| 14. | 14. | 13. | 13. | 13. | 13. | 13. | 12. | 12. | 12. |
| 12. | 12. | 11. | 11. | 11. | 11. | 11. | 10. | 10. | 10. |
| 10. | 10. | 10. | 9. | 9. | 9. | 9. | 9. | 9. | 9. |
| 8. | 8. | 8. | 8. | 8. | 8. | 8. | 7. | 7. | 7. |
| 7. | 7. | 7. | 7. | 7. | 7. | 6. | 6. | 6. | 6. |
| 6. | 6. | 6. | 6. | 6. | 5. | 5. | 5. | 5. | 5. |
| 5. | 5. | 5. | 5. | 5. | 5. | 5. | 4. | 4. | 4. |
| 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4. | 4. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |

*** *** *** *** ***

HYDROGRAPH AT STATION S-H

TOTAL RAINFALL = 12.76, TOTAL LOSS = 2.94, TOTAL EXCESS = 9.82

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1626. | 5.03 | (CFS) | 825. | 324. | 324. | 324. |
| | | (INCHES) | 8.924 | 9.709 | 9.709 | 9.709 |
| | | (AC-FT) | 409. | 445. | 445. | 445. |

CUMULATIVE AREA = .86 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
138 KK        *     C-C3   *
              *            *
              **************
```

Combine R-G-2 and S-H

140 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

*** *** *** *** ***

HYDROGRAPH AT STATION C-C3

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2930. | 5.03 | (CFS) | 1443. | 634. | 634. | 634. |
| | | (INCHES) | 8.762 | 10.678 | 10.678 | 10.678 |
| | | (AC-FT) | 715. | 872. | 872. | 872. |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
141 KK    *      DIVH  *
          *            *
          **************
```

Divert flows in excess of the Signal Butte Floodway capacity

| | | | | |
|---|---|---|---|---|
| DT | DIVERSION ISTAD | DV-H | DIVERSION HYDROGRAPH IDENTIFICATION | |
| DI | INFLOW | .00 | 2777.00 | 2778.00 |
| DQ | DIVERTED FLOW | .00 | .00 | 1.00 |

***

*** *** *** *** ***

DIVERSION HYDROGRAPH DV-H

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 153. | 5.03 | (CFS) | 11. | 4. | 4. | 4. |
| | | (INCHES) | .064 | .064 | .064 | .064 |
| | | (AC-FT) | 5. | 5. | 5. | 5. |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION DIVH

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2777. | 4.67 | (CFS) | 1432. | 630. | 630. | 630. |
| | | (INCHES) | 8.698 | 10.614 | 10.614 | 10.614 |
| | | (AC-FT) | 710. | 867. | 867. | 867. |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
146 KK        *       R-H  *
              *            *
              **************
                                Route DIVH to S-I

                 HYDROGRAPH ROUTING DATA

148 RS             STORAGE ROUTING
                        NSTPS          2  NUMBER OF SUBREACHES
                         ITYP       FLOW  TYPE OF INITIAL CONDITION
                       RSVRIC      -1.00  INITIAL CONDITION
                            X        .00 WORKING R AND D COEFFICIENT

149 RC             NORMAL DEPTH CHANNEL
                          ANL       .016  LEFT OVERBANK N-VALUE
                         ANCH       .016  MAIN CHANNEL N-VALUE
                          ANR       .016  RIGHT OVERBANK N-VALUE
                        RLNTH      3938.  REACH LENGTH
                          SEL      .0152  ENERGY SLOPE
                        ELMAX         .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                          CROSS-SECTION DATA
                            --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
151 RY        ELEVATION      7.50      7.50      7.50       .00       .00      7.50      7.50      7.50
150 RX        DISTANCE        .00      1.00      2.00      2.10     16.10     16.20     17.00     18.00

                                                                  ***

                                          COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

          STORAGE        .00       .50      1.00      1.50      2.00      2.50      3.00      3.51      4.01      4.51
          OUTFLOW        .00     32.94    101.07    192.33    301.25    424.31    559.06    703.65    856.66   1016.94
        ELEVATION        .00       .39       .79      1.18      1.58      1.97      2.37      2.76      3.16      3.55

          STORAGE       5.01      5.52      6.02      6.53      7.03      7.54      8.04      8.55      9.05      9.56
          OUTFLOW    1183.57   1355.80   1533.00   1714.64   1900.26   2089.49   2281.98   2477.45   2675.65   2876.36
        ELEVATION       3.95      4.34      4.74      5.13      5.53      5.92      6.32      6.71      7.11      7.50


*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN     1715. TO     2876.
                THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
                THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

     ***            ***            ***            ***            ***

                         HYDROGRAPH AT STATION      R-H

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   2777.       4.73       (CFS)     1432.       630.        630.        630.
                        (INCHES)    8.698     10.598      10.598      10.598
                         (AC-FT)    710.       865.        865.        865.

PEAK STORAGE   TIME                          MAXIMUM AVERAGE STORAGE
  (AC-FT)      (HR)                 6-HR       24-HR       72-HR     16.63-HR
      5.       4.73                   3.         1.          1.          1.
```

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 7.30 | 4.73 | 4.39 | 2.24 | 2.24 | 2.24 |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
152 KK        *      S-I   *
              *            *
              **************
```

Runoff from Sub-basin I

SUBBASIN RUNOFF DATA

154 BA SUBBASIN CHARACTERISTICS

TAREA 1.32 SUBBASIN AREA

PRECIPITATION DATA

88 PB STORM 12.76 BASIN TOTAL PRECIPITATION

88 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

155 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .30 | STARTING LOSS |
| DTH | .25 | MOISTURE DEFICIT |
| PSIF | 4.50 | WETTING FRONT SUCTION |
| XKSAT | .39 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 15.00 | PERCENT IMPERVIOUS AREA |

156 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | 2.01 | TIME OF CONCENTRATION |
| R | 1.75 | STORAGE COEFFICIENT |

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 2.01 HR, R= 1.75 HR

SNYDER TP= 1.87 HR, CP= .62

UNIT HYDROGRAPH

300 END-OF-PERIOD ORDINATES

VOLUME = .99

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 3. | 6. | 9. | 14. | 18. | 23. | 29. | 34. | 40. |
| 46. | 53. | 59. | 66. | 73. | 80. | 87. | 94. | 102. | 110. |
| 117. | 125. | 133. | 141. | 149. | 157. | 165. | 173. | 182. | 190. |
| 198. | 206. | 214. | 221. | 228. | 235. | 241. | 247. | 253. | 258. |
| 263. | 268. | 272. | 276. | 280. | 283. | 286. | 289. | 291. | 293. |
| 294. | 295. | 296. | 296. | 296. | 296. | 294. | 293. | 291. | 288. |
| 283. | 278. | 273. | 268. | 263. | 258. | 253. | 248. | 243. | 239. |
| 234. | 230. | 226. | 221. | 217. | 213. | 209. | 205. | 201. | 197. |
| 194. | 190. | 186. | 183. | 179. | 176. | 173. | 170. | 166. | 163. |
| 160. | 157. | 154. | 151. | 148. | 146. | 143. | 140. | 138. | 135. |
| 132. | 130. | 127. | 125. | 123. | 120. | 118. | 116. | 114. | 112. |
| 109. | 107. | 105. | 103. | 101. | 100. | 98. | 96. | 94. | 92. |
| 90. | 89. | 87. | 85. | 84. | 82. | 81. | 79. | 78. | 76. |
| 75. | 73. | 72. | 71. | 69. | 68. | 67. | 65. | 64. | 63. |
| 62. | 61. | 60. | 58. | 57. | 56. | 55. | 54. | 53. | 52. |
| 51. | 50. | 49. | 48. | 47. | 46. | 46. | 45. | 44. | 43. |
| 42. | 41. | 41. | 40. | 39. | 38. | 38. | 37. | 36. | 36. |
| 35. | 34. | 34. | 33. | 32. | 32. | 31. | 31. | 30. | 29. |
| 29. | 28. | 28. | 27. | 27. | 26. | 26. | 25. | 25. | 24. |
| 24. | 23. | 23. | 23. | 22. | 22. | 21. | 21. | 21. | 20. |
| 20. | 19. | 19. | 19. | 18. | 18. | 18. | 17. | 17. | 17. |
| 16. | 16. | 16. | 15. | 15. | 15. | 15. | 14. | 14. | 14. |
| 13. | 13. | 13. | 13. | 13. | 12. | 12. | 12. | 12. | 11. |
| 11. | 11. | 11. | 11. | 10. | 10. | 10. | 10. | 10. | 9. |
| 9. | 9. | 9. | 9. | 9. | 8. | 8. | 8. | 8. | 8. |
| 8. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 6. |
| 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 5. | 5. |
| 5. | 5. | 5. | 5. | 5. | 5. | 5. | 5. | 4. | 4. |
| 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |

*** *** *** *** ***

HYDROGRAPH AT STATION S-I

TOTAL RAINFALL = 12.76, TOTAL LOSS = 2.84, TOTAL EXCESS = 9.92

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2706. | 5.00 | (CFS) | 1308. | 505. | 505. | 505. |
| | | (INCHES) | 9.211 | 9.857 | 9.857 | 9.857 |
| | | (AC-FT) | 648. | 694. | 694. | 694. |

CUMULATIVE AREA = 1.32 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
157 KK        *      C-C4  *
              *            *
              **************
                                Combine R-H and S-I

159 HC            HYDROGRAPH COMBINATION
                        ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                                  ***

     ***              ***              ***              ***              ***

                          HYDROGRAPH AT STATION     C-C4

PEAK FLOW     TIME                              MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                   6-HR       24-HR       72-HR     16.63-HR
   5483.      5.00        (CFS)      2740.       1134.       1134.       1134.
                         (INCHES)    8.935      10.255      10.255      10.255
                          (AC-FT)    1359.       1559.       1559.       1559.

                         CUMULATIVE AREA =    2.85 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
160 KK        *      DIVI  *
              *            *
              **************
                                Divert flows in excess of the Signal Butte Floodway capacity

    DT            DIVERSION
                        ISTAD        DV-I  DIVERSION HYDROGRAPH IDENTIFICATION

    DI              INFLOW          .00   2872.00   2873.00

    DQ       DIVERTED FLOW          .00       .00      1.00

                                                                  ***

     ***              ***              ***              ***              ***

                          DIVERSION HYDROGRAPH     DV-I

PEAK FLOW     TIME                              MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                   6-HR       24-HR       72-HR     16.63-HR
   2611.      5.00        (CFS)       655.        236.        236.        236.
                         (INCHES)    2.137       2.137       2.137       2.137
                          (AC-FT)     325.        325.        325.        325.

                         CUMULATIVE AREA =    2.85 SQ MI
```

```
***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION     DIVI

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   2872.      3.83       (CFS)     2084.       898.        898.        898.
                       (INCHES)    6.797      8.118       8.118       8.118
                        (AC-FT)    1034.      1234.       1234.       1234.

                     CUMULATIVE AREA =    2.85 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
165 KK    *     S-A1   *
          *            *
          **************
                    Runoff from Sub-basin A1

             SUBBASIN RUNOFF DATA

167 BA          SUBBASIN CHARACTERISTICS
                     TAREA          .96  SUBBASIN AREA

                PRECIPITATION DATA

 88 PB               STORM       12.76  BASIN TOTAL PRECIPITATION

 88 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

168 LG          GREEN AND AMPT LOSS RATE
                     STRTL         .30  STARTING LOSS
                       DTH         .26  MOISTURE DEFICIT
                      PSIF        4.25  WETTING FRONT SUCTION
                     XKSAT         .47  HYDRAULIC CONDUCTIVITY
```

```
                    RTIMP       16.00  PERCENT IMPERVIOUS AREA

169 UC          CLARK UNITGRAPH
                         TC        1.22  TIME OF CONCENTRATION
                          R         .93  STORAGE COEFFICIENT

                SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                        ***

                                                UNIT HYDROGRAPH PARAMETERS
                                         CLARK   TC=  1.22 HR,       R=   .93 HR
                                        SNYDER   TP=  1.11 HR,      CP=   .66

                                                   UNIT HYDROGRAPH
                                            167 END-OF-PERIOD ORDINATES
            2.      8.     17.     27.     38.     51.     65.     79.     94.    110.
          126.    142.    159.    176.    193.    211.    229.    247.    264.    281.
          297.    312.    325.    336.    347.    356.    364.    371.    376.    380.
          383.    384.    384.    382.    379.    373.    364.    352.    340.    328.
          316.    305.    294.    284.    274.    264.    255.    246.    237.    229.
          221.    213.    205.    198.    191.    184.    178.    171.    165.    159.
          154.    148.    143.    138.    133.    128.    124.    120.    115.    111.
          107.    103.    100.     96.     93.     90.     86.     83.     80.     78.
           75.     72.     70.     67.     65.     62.     60.     58.     56.     54.
           52.     50.     49.     47.     45.     44.     42.     41.     39.     38.
           36.     35.     34.     33.     32.     30.     29.     28.     27.     26.
           25.     24.     24.     23.     22.     21.     20.     20.     19.     18.
           18.     17.     16.     16.     15.     15.     14.     14.     13.     13.
           12.     12.     11.     11.     11.     10.     10.     10.      9.      9.
            9.      8.      8.      8.      7.      7.      7.      7.      6.      6.
            6.      6.      6.      5.      5.      5.      5.      5.      4.      4.
            4.      4.      4.      4.      4.      3.      3.

   ***            ***            ***            ***            ***

                     HYDROGRAPH AT STATION     S-A1

   TOTAL RAINFALL =   12.76, TOTAL LOSS =    3.08, TOTAL EXCESS =    9.68

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  3197.       4.27        (CFS)     984.        359.        359.        359.
                         (INCHES)  9.527       9.634       9.634       9.634
                         (AC-FT)   488.        493.        493.        493.

                     CUMULATIVE AREA =     .96 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
170 KK    *      C-C5  *
          *            *
          **************
                     Combine S-A1 and DIVI
```

```
172 HC          HYDROGRAPH COMBINATION
                     ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

    ***            ***            ***            ***            ***

                       HYDROGRAPH AT STATION     C-C5

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   6069.      4.27       (CFS)     3055.       1257.       1257.       1257.
                       (INCHES)    7.453       8.500       8.500       8.500
                        (AC-FT)    1515.       1728.       1728.       1728.

                       CUMULATIVE AREA =    3.81 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
173 KK    *     S-B1   *
          *            *
          **************
                         Runoff from Sub-basin B1

             SUBBASIN RUNOFF DATA

175 BA          SUBBASIN CHARACTERISTICS
                     TAREA        4.09  SUBBASIN AREA

                PRECIPITATION DATA

 88 PB               STORM       12.76  BASIN TOTAL PRECIPITATION

 88 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
```

176 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .29 | STARTING LOSS |
| DTH | .25 | MOISTURE DEFICIT |
| PSIF | 4.45 | WETTING FRONT SUCTION |
| XKSAT | .41 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 11.00 | PERCENT IMPERVIOUS AREA |

177 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | 1.86 | TIME OF CONCENTRATION |
| R | 1.29 | STORAGE COEFFICIENT |

178 UA ACCUMULATED-AREA VS. TIME, 11 ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .0 | 3.0 | 5.0 | 8.0 | 12.0 | 20.0 | 43.0 | 75.0 | 90.0 | 96.0 |
| 100.0 | | | | | | | | | |

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.86 HR, R= 1.29 HR

SNYDER TP= 1.56 HR, CP= .76

UNIT HYDROGRAPH

240 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5. | 16. | 27. | 37. | 47. | 56. | 62. | 68. | 74. | 79. |
| 84. | 91. | 99. | 107. | 116. | 123. | 132. | 141. | 152. | 163. |
| 173. | 183. | 198. | 220. | 243. | 266. | 288. | 312. | 363. | 437. |
| 509. | 579. | 648. | 723. | 813. | 908. | 1000. | 1091. | 1179. | 1236. |
| 1260. | 1282. | 1304. | 1325. | 1340. | 1338. | 1325. | 1313. | 1301. | 1290. |
| 1276. | 1259. | 1241. | 1224. | 1207. | 1189. | 1165. | 1135. | 1106. | 1078. |
| 1050. | 1024. | 997. | 972. | 947. | 923. | 900. | 877. | 854. | 832. |
| 811. | 791. | 770. | 751. | 732. | 713. | 695. | 677. | 660. | 643. |
| 626. | 610. | 595. | 580. | 565. | 551. | 536. | 523. | 509. | 496. |
| 484. | 471. | 459. | 448. | 436. | 425. | 414. | 404. | 393. | 383. |
| 374. | 364. | 355. | 346. | 337. | 328. | 320. | 312. | 304. | 296. |
| 289. | 281. | 274. | 267. | 260. | 254. | 247. | 241. | 235. | 229. |
| 223. | 217. | 212. | 206. | 201. | 196. | 191. | 186. | 181. | 177. |
| 172. | 168. | 163. | 159. | 155. | 151. | 147. | 144. | 140. | 136. |
| 133. | 130. | 126. | 123. | 120. | 117. | 114. | 111. | 108. | 105. |
| 103. | 100. | 97. | 95. | 93. | 90. | 88. | 86. | 83. | 81. |
| 79. | 77. | 75. | 73. | 71. | 70. | 68. | 66. | 64. | 63. |
| 61. | 60. | 58. | 57. | 55. | 54. | 52. | 51. | 50. | 49. |
| 47. | 46. | 45. | 44. | 43. | 42. | 40. | 39. | 38. | 37. |
| 37. | 36. | 35. | 34. | 33. | 32. | 31. | 30. | 30. | 29. |
| 28. | 27. | 27. | 26. | 25. | 25. | 24. | 24. | 23. | 22. |
| 22. | 21. | 21. | 20. | 20. | 19. | 19. | 18. | 18. | 17. |
| 17. | 16. | 16. | 16. | 15. | 15. | 14. | 14. | 14. | 13. |
| 13. | 13. | 12. | 12. | 12. | 11. | 11. | 11. | 11. | 10. |

*** *** *** *** ***

HYDROGRAPH AT STATION S-B1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.04, TOTAL EXCESS = 9.72

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 11044. | 4.83 | (CFS) | 4137. | 1535. | 1535. | 1535. |
| | | (INCHES) | 9.403 | 9.672 | 9.672 | 9.672 |
| | | (AC-FT) | 2051. | 2110. | 2110. | 2110. |

CUMULATIVE AREA = 4.09 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
180 KK    *      C-C6  *
          *            *
          **************
```

Combine C-C5 and S-B1

182 HC HYDROGRAPH COMBINATION
ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

*** *** *** *** ***

HYDROGRAPH AT STATION C-C6

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 16321. | 4.73 | (CFS) | 7191. | 2791. | 2791. | 2791. |
| | | (INCHES) | 8.462 | 9.106 | 9.106 | 9.106 |
| | | (AC-FT) | 3566. | 3837. | 3837. | 3837. |

CUMULATIVE AREA = 7.90 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
183 KK    *      S-B2  *
          *            *
          **************
```

Runoff from Sub-basin B2

SUBBASIN RUNOFF DATA

185 BA SUBBASIN CHARACTERISTICS
TAREA 1.36 SUBBASIN AREA

PRECIPITATION DATA

88 PB STORM 12.76 BASIN TOTAL PRECIPITATION

88 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

186 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .31 | STARTING LOSS |
| DTH | .26 | MOISTURE DEFICIT |
| PSIF | 4.35 | WETTING FRONT SUCTION |
| XKSAT | .46 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 15.00 | PERCENT IMPERVIOUS AREA |

187 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | 1.87 | TIME OF CONCENTRATION |
| R | 1.64 | STORAGE COEFFICIENT |

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.87 HR, R= 1.64 HR

SNYDER TP= 1.74 HR, CP= .62

UNIT HYDROGRAPH

291 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 3. | 7. | 12. | 17. | 22. | 28. | 35. | 42. | 49. |
| 56. | 64. | 72. | 80. | 89. | 97. | 106. | 115. | 124. | 133. |
| 142. | 152. | 161. | 171. | 180. | 190. | 200. | 210. | 220. | 229. |
| 238. | 247. | 255. | 263. | 270. | 277. | 283. | 289. | 295. | 300. |
| 305. | 309. | 313. | 316. | 319. | 321. | 323. | 325. | 326. | 327. |
| 327. | 326. | 325. | 323. | 320. | 317. | 311. | 305. | 299. | 293. |
| 287. | 281. | 276. | 270. | 265. | 259. | 254. | 249. | 244. | 239. |
| 234. | 230. | 225. | 220. | 216. | 212. | 207. | 203. | 199. | 195. |
| 191. | 187. | 184. | 180. | 176. | 173. | 169. | 166. | 163. | 159. |
| 156. | 153. | 150. | 147. | 144. | 141. | 138. | 135. | 133. | 130. |
| 127. | 125. | 122. | 120. | 117. | 115. | 113. | 111. | 108. | 106. |
| 104. | 102. | 100. | 98. | 96. | 94. | 92. | 90. | 88. | 87. |
| 85. | 83. | 81. | 80. | 78. | 77. | 75. | 74. | 72. | 71. |
| 69. | 68. | 67. | 65. | 64. | 63. | 61. | 60. | 59. | 58. |
| 57. | 55. | 54. | 53. | 52. | 51. | 50. | 49. | 48. | 47. |
| 46. | 45. | 44. | 43. | 43. | 42. | 41. | 40. | 39. | 38. |
| 38. | 37. | 36. | 35. | 35. | 34. | 33. | 33. | 32. | 31. |
| 31. | 30. | 30. | 29. | 28. | 28. | 27. | 27. | 26. | 26. |
| 25. | 25. | 24. | 24. | 23. | 23. | 22. | 22. | 21. | 21. |
| 20. | 20. | 20. | 19. | 19. | 18. | 18. | 18. | 17. | 17. |
| 17. | 16. | 16. | 16. | 15. | 15. | 15. | 14. | 14. | 14. |
| 14. | 13. | 13. | 13. | 13. | 12. | 12. | 12. | 12. | 11. |
| 11. | 11. | 11. | 10. | 10. | 10. | 10. | 10. | 9. | 9. |
| 9. | 9. | 9. | 9. | 8. | 8. | 8. | 8. | 8. | 8. |
| 7. | 7. | 7. | 7. | 7. | 7. | 7. | 6. | 6. | 6. |

```
          6.      6.      6.      6.      6.      5.      5.      5.      5.      5.
          5.      5.      5.      5.      5.      4.      4.      4.      4.      4.
          4.      4.      4.      4.      4.      4.      4.      3.      3.      3.
          3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
          3.

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION     S-B2

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    3.10, TOTAL EXCESS =    9.66

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR      24-HR      72-HR     16.63-HR
  2907.       4.87       (CFS)      1329.      507.       507.        507.
                       (INCHES)     9.085     9.612      9.612       9.612
                        (AC-FT)     659.      697.       697.        697.

                      CUMULATIVE AREA =    1.36 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
188 KK    *     C-C7   *
          *            *
          **************
                    Combine C-C6 and S-B2

190 HC          HYDROGRAPH COMBINATION
                     ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                        ***

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION     C-C7

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR      24-HR      72-HR     16.63-HR
  19180.      4.73       (CFS)      8519.     3299.      3299.       3299.
                       (INCHES)     8.553     9.181      9.181       9.181
                        (AC-FT)     4225.     4535.      4535.       4535.

                      CUMULATIVE AREA =    9.26 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
191 KK    *     S-C1   *
          *            *
```

```
**************
                    Runoff from Sub-basin C1

          SUBBASIN RUNOFF DATA

193 BA        SUBBASIN CHARACTERISTICS
                   TAREA        2.54  SUBBASIN AREA

              PRECIPITATION DATA

 88 PB             STORM       12.76  BASIN TOTAL PRECIPITATION

 88 PI          INCREMENTAL PRECIPITATION PATTERN
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                  .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                  .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                  .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

194 LG        GREEN AND AMPT LOSS RATE
                  STRTL         .31  STARTING LOSS
                    DTH         .26  MOISTURE DEFICIT
                   PSIF        4.35  WETTING FRONT SUCTION
                  XKSAT         .46  HYDRAULIC CONDUCTIVITY
                  RTIMP       15.00  PERCENT IMPERVIOUS AREA

195 UC        CLARK UNITGRAPH
                     TC        1.07  TIME OF CONCENTRATION
                      R         .63  STORAGE COEFFICIENT

196 UA        ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                   .0       5.0      16.0      30.0      65.0      77.0      84.0      90.0      94.0      97.0
                100.0

                                                  ***

                                          UNIT HYDROGRAPH PARAMETERS
                                   CLARK   TC=  1.07 HR,       R=   .63 HR
                                  SNYDER   TP=   .55 HR,      CP=   .47

                                          UNIT HYDROGRAPH
                                   114 END-OF-PERIOD ORDINATES
            20.       59.       95.      149.      224.      299.      378.      465.      552.      665.
           856.     1090.     1297.     1402.     1424.     1446.     1447.     1429.     1410.     1390.
          1367.     1343.     1317.     1284.     1250.     1215.     1179.     1141.     1106.     1073.
          1041.     1011.      971.      922.      874.      829.      786.      745.      707.      670.
           635.      602.      571.      541.      513.      487.      461.      437.      415.      393.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 373. | 354. | 335. | 318. | 301. | 286. | 271. | 257. | 244. | 231. |
| 219. | 208. | 197. | 187. | 177. | 168. | 159. | 151. | 143. | 136. |
| 129. | 122. | 116. | 110. | 104. | 98. | 93. | 89. | 84. | 80. |
| 75. | 72. | 68. | 64. | 61. | 58. | 55. | 52. | 49. | 47. |
| 44. | 42. | 40. | 38. | 36. | 34. | 32. | 31. | 29. | 27. |
| 26. | 25. | 23. | 22. | 21. | 20. | 19. | 18. | 17. | 16. |
| 15. | 14. | 14. | 13. | | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-C1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.10, TOTAL EXCESS = 9.66

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 10683. | 3.87 | (CFS) | 2616. | 947. | 947. | 947. |
| | | (INCHES) | 9.575 | 9.613 | 9.613 | 9.613 |
| | | (AC-FT) | 1297. | 1302. | 1302. | 1302. |

CUMULATIVE AREA = 2.54 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
198 KK    *      C-C8  *
          *            *
          **************
```

Combine C-C7 and S-C1

200 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

*** *** *** *** ***

HYDROGRAPH AT STATION C-C8

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 25000. | 4.53 | (CFS) | 11067. | 4246. | 4246. | 4246. |
| | | (INCHES) | 8.720 | 9.274 | 9.274 | 9.274 |
| | | (AC-FT) | 5488. | 5837. | 5837. | 5837. |

CUMULATIVE AREA = 11.80 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
```

```
201 KK     *      S-D1  *
           *            *
           **************
                    Runoff from Sub-basin D1

              SUBBASIN RUNOFF DATA

203 BA          SUBBASIN CHARACTERISTICS
                     TAREA        1.15  SUBBASIN AREA

                PRECIPITATION DATA

 88 PB                STORM       12.76  BASIN TOTAL PRECIPITATION

 88 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

204 LG          GREEN AND AMPT LOSS RATE
                     STRTL        .30  STARTING LOSS
                       DTH        .27  MOISTURE DEFICIT
                      PSIF       3.64  WETTING FRONT SUCTION
                     XKSAT        .67  HYDRAULIC CONDUCTIVITY
                     RTIMP      17.00  PERCENT IMPERVIOUS AREA

205 UC          CLARK UNITGRAPH
                        TC        .90  TIME OF CONCENTRATION
                         R        .65  STORAGE COEFFICIENT

                SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                  ***

                                          UNIT HYDROGRAPH PARAMETERS
                                   CLARK   TC=   .90 HR,      R=   .65 HR
                                  SNYDER   TP=   .80 HR,     CP=   .67

                                          UNIT HYDROGRAPH
                                     118 END-OF-PERIOD ORDINATES
                     6.        21.       44.       71.      101.      133.      168.      204.      241.      280.
                   319.       359.      399.      440.      478.      513.      543.      569.      591.      609.
                   623.       633.      639.      641.      638.      629.      614.      589.      559.      531.
                   505.       479.      455.      433.      411.      390.      371.      352.      335.      318.
                   302.       287.      272.      259.      246.      234.      222.      211.      200.      190.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 181. | 172. | 163. | 155. | 147. | 140. | 133. | 126. | 120. | 114. |
| 108. | 103. | 98. | 93. | 88. | 84. | 79. | 75. | 72. | 68. |
| 65. | 61. | 58. | 55. | 53. | 50. | 47. | 45. | 43. | 41. |
| 39. | 37. | 35. | 33. | 31. | 30. | 28. | 27. | 26. | 24. |
| 23. | 22. | 21. | 20. | 19. | 18. | 17. | 16. | 15. | 15. |
| 14. | 13. | 12. | 12. | 11. | 11. | 10. | 10. | 9. | 9. |
| 8. | 8. | 7. | 7. | 7. | 6. | 6. | 6. | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-D1

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.46, TOTAL EXCESS = 9.30

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 4833. | 3.97 | (CFS) | 1139. | 413. | 413. | 413. |
| | | (INCHES) | 9.207 | 9.251 | 9.251 | 9.251 |
| | | (AC-FT) | 565. | 567. | 567. | 567. |

CUMULATIVE AREA = 1.15 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
206 KK        *      C-C9  *
              *            *
              **************
```

Combine C-C8 and S-D1

208 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

*** *** *** *** ***

HYDROGRAPH AT STATION C-C9

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 28208. | 4.43 | (CFS) | 12187. | 4659. | 4659. | 4659. |
| | | (INCHES) | 8.749 | 9.272 | 9.272 | 9.272 |
| | | (AC-FT) | 6043. | 6404. | 6404. | 6404. |

CUMULATIVE AREA = 12.95 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
```

```
209 KK     *       RES  *
           *            *
           **************
```

Spook Hill Reservoir Routing
See DMJM+HARRIS Technical Report No. 1 for supporting details
behind rating curves.

NGVD 29 elevations used in the computations.

Sediment Storage Volume Below Principle Spillway = 271 Ac-Ft (Elev=1577.5')

HYDROGRAPH ROUTING DATA

```
217 RS          STORAGE ROUTING
                     NSTPS          1  NUMBER OF SUBREACHES
                      ITYP       STOR  TYPE OF INITIAL CONDITION
                    RSVRIC        .00  INITIAL CONDITION
                         X        .00 WORKING R AND D COEFFICIENT

218 SV            STORAGE         .0     287.0     346.0     474.9     693.0    1120.0    1631.0    1919.0    2231.0    2927.0
                               3722.0    4158.0

220 SQ          DISCHARGE         0.        0.      250.      500.      750.      990.     2860.     4750.     7000.    12750.
                               19240.    23050.

222 SE          ELEVATION     1575.10   1577.50   1578.00   1578.80   1580.00   1582.00   1584.00   1585.00   1586.00   1588.00
                              1590.00   1591.00

                                                                  ***

    ***             ***             ***             ***             ***
```

HYDROGRAPH AT STATION RES

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 14478. | 5.73 | (CFS) | 9068. | 3934. | 3934. | 3934. |
| | | (INCHES) | 6.510 | 7.830 | 7.830 | 7.830 |
| | | (AC-FT) | 4496. | 5408. | 5408. | 5408. |

| PEAK STORAGE (AC-FT) | TIME (HR) | MAXIMUM AVERAGE STORAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 3139. | 5.73 | 2466. | 1427. | 1427. | 1427. |

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 1588.53 | 5.73 | 1586.62 | 1582.45 | 1582.45 | 1582.45 |

CUMULATIVE AREA = 12.95 SQ MI

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

| OPERATION | STATION | PEAK FLOW | TIME OF PEAK | AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR | 24-HOUR | 72-HOUR | BASIN AREA | MAXIMUM STAGE | TIME OF MAX STAGE |
|---|---|---|---|---|---|---|---|---|---|
| HYDROGRAPH AT | S-IN | 157. | .80 | 157. | 150. | 150. | .00 | | |
| HYDROGRAPH AT | S-F | 529. | 4.13 | 156. | 57. | 57. | .15 | | |
| 2 COMBINED AT | C-C1 | 686. | 4.13 | 313. | 206. | 206. | .15 | | |
| DIVERSION TO | DV-F | 0. | 4.13 | 0. | 0. | 0. | .15 | | |
| HYDROGRAPH AT | DIVF | 686. | 4.13 | 313. | 206. | 206. | .15 | | |
| ROUTED TO | R-F | 679. | 4.37 | 313. | 202. | 202. | .15 | 6.97 | 4.37 |
| HYDROGRAPH AT | S-G | 2580. | 4.03 | 576. | 208. | 208. | .52 | | |
| 2 COMBINED AT | C-C2 | 3161. | 4.07 | 887. | 410. | 410. | .67 | | |
| DIVERSION TO | DV-G | 1857. | 3.47 | 259. | 94. | 94. | .67 | | |
| HYDROGRAPH AT | DIVG | 1304. | 3.47 | 627. | 317. | 317. | .67 | | |
| ROUTED TO | R-G-1 | 1304. | 3.93 | 627. | 311. | 311. | .67 | 8.22 | 3.97 |
| ROUTED TO | R-G-2 | 1304. | 4.00 | 627. | 310. | 310. | .67 | 4.25 | 4.00 |
| HYDROGRAPH AT | S-H | 1626. | 5.03 | 825. | 324. | 324. | .86 | | |
| 2 COMBINED AT | C-C3 | 2930. | 5.03 | 1443. | 634. | 634. | 1.53 | | |
| DIVERSION TO | DV-H | 153. | 4.67 | 11. | 4. | 4. | 1.53 | | |
| HYDROGRAPH AT | DIVH | 2777. | 4.67 | 1432. | 630. | 630. | 1.53 | | |
| ROUTED TO | R-H | 2777. | 4.73 | 1432. | 630. | 630. | 1.53 | 7.30 | 4.73 |
| HYDROGRAPH AT | S-I | 2706. | 5.00 | 1308. | 505. | 505. | 1.32 | | |
| 2 COMBINED AT | C-C4 | 5483. | 5.00 | 2740. | 1134. | 1134. | 2.85 | | |
| DIVERSION TO | DV-I | 2611. | 3.83 | 655. | 236. | 236. | 2.85 | | |
| HYDROGRAPH AT | DIVI | 2872. | 3.83 | 2084. | 898. | 898. | 2.85 | | |
| HYDROGRAPH AT | S-A1 | 3197. | 4.27 | 984. | 359. | 359. | .96 | | |
| 2 COMBINED AT | C-C5 | 6069. | 4.27 | 3055. | 1257. | 1257. | 3.81 | | |
| HYDROGRAPH AT | S-B1 | 11044. | 4.83 | 4137. | 1535. | 1535. | 4.09 | | |
| 2 COMBINED AT | C-C6 | 16321. | 4.73 | 7191. | 2791. | 2791. | 7.90 | | |
| HYDROGRAPH AT | S-B2 | 2907. | 4.87 | 1329. | 507. | 507. | 1.36 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 COMBINED AT | C-C7 | 19180. | 4.73 | 8519. | 3299. | 3299. | 9.26 | | |
| HYDROGRAPH AT | S-C1 | 10683. | 3.87 | 2616. | 947. | 947. | 2.54 | | |
| 2 COMBINED AT | C-C8 | 25000. | 4.53 | 11067. | 4246. | 4246. | 11.80 | | |
| HYDROGRAPH AT | S-D1 | 4833. | 3.97 | 1139. | 413. | 413. | 1.15 | | |
| 2 COMBINED AT | C-C9 | 28208. | 4.43 | 12187. | 4659. | 4659. | 12.95 | | |
| ROUTED TO | RES | 14478. | 5.73 | 9068. | 3934. | 3934. | 12.95 | 1588.53 | 5.73 |

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

# Appendix E4

## Recommended Existing Hydrologic Conditions Model
## One-Half PMF
## (Spkhpmf.dat)

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   25OCT01  TIME  11:13:39  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*   U.S. ARMY CORPS OF ENGINEERS       *
*   HYDROLOGIC ENGINEERING CENTER      *
*         609 SECOND STREET            *
*      DAVIS, CALIFORNIA 95616         *
*          (916) 756-1104              *
*                                      *
****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X       X     X        XX
X     X  X       X               X
XXXXXXX  XXXX    X       XXXXX   X
X     X  X       X               X
X     X  X       X     X         X
X     X  XXXXXXX   XXXXX        XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL  LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
  2           ID   POWER ROAD TO UNIVERSITY DRIVE
  3           ID
  4           ID   FILENAME: SPKHPMF.DAT
  5           ID
  6           ID   THIS MODEL REPRESENTS EXISTING CONDITIONS FOR THE CONTRIBUTING WATERSHED
  7           ID   TO THE SPOOK HILL FRS AND THE UNCONTROLLED DRAINAGE AREA BETWEEN THE PASS
  8           ID   MOUNTAIN DIVERSION AND THE SIGNAL BUTTE FLOODWAY. THE PROCEDURES AND
  9           ID   GUIDELINES IN HMR 49 AND THE FCDMC HYDROLOGY MANUAL WERE USED.
 10           ID
 11           ID   HEC-1 MODEL PARAMETERS:
 12           ID        DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS
 13           ID                WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE
 14           ID                SUBBASIN LENGTH, SLOPE AND AREA.
 15           ID        HYDROGRAPH: HALF OF THE PROBABLE MAXIMUM FLOOD (0.5 PMF)
 16           ID        INFLOW HYDROGRAPH: THE MAXIMUM 100-YEAR, 24-HOUR STORM SIGNAL BUTTE FRS
 17           ID                           PRINCIPAL SPILLWAY OUTFLOW (157 cfs) WAS ASSUMED
 18           ID                           FOR THE UPPER CONTRIBUTING WATERSHED.
 19           ID        PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION COMPUTED
 20           ID                             USING THE PROCEDURES AND GUIDELINES IN HMR 49.
 21           ID        RAINFALL DURATION: 6 HRS
 22           ID        RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.
 23           ID        LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC
 24           ID                HYDROLOGY MANUAL (1995).
 25           ID        RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH
 26           ID        CHANNEL ROUTING: NORMAL DEPTH CHANNEL ROUTING
 27           ID        RESERVOIR ROUTING: MODIFIED PULS RESERVOIR ROUTING
             *DIAGRAM
 28           IT       2                    500
 29           IO       3
 30           JR     FLOW     0.5

 31           KK     S-IN
 32           KM   SIGNAL BUTTE FRS INFLOW
 33           BA   0.001
 34           KM   SIGNAL BUTTE FRS INFLOW
 35           KM   PEAK DISCHARGE DOUBLED TO ACCOUNT FOR HALF FLOW RATIO OF JR RECORD
 36           BA   0.001
 37           QI     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 38           QI     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 39           QI     0.0     0.0     0.0     0.0   314.0   314.0   314.0   314.0   314.0   314.0
 40           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 41           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 42           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 43           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 44           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 45           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 46           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 47           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 48           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 49           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 50           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 51           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 52           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
 53           QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  54          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  55          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  56          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  57          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  58          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  59          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  60          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  61          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  62          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  63          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  64          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  65          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  66          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  67          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  68          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  69          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  70          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  71          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  72          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  73          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  74          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  75          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  76          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  77          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  78          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  79          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  80          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  81          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  82          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  83          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  84          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  85          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0
  86          QI   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0   314.0

  87          KK     S-F
  88          KM    Runoff from Sub-basin F
  89          BA    0.15
  90          IN      15
  91          PB   12.76
  92          KM    HMR 49 (1977) was used to distribute the local PMP
  93          PC    .000    .008    .016    .023    .031    .041    .051    .061    .070    .098
  94          PC    .125    .152    .180    .648    .789    .859    .914    .928    .941    .955
  95          PC    .969    .977    .984    .992   1.000
  96          LG    .300    .250   4.500    .370     9.0
  97          UC   1.040   0.908

  98          KK    C-C1
  99          KM    Combine S-IN and S-F
 100          HC       2
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 101          KK    DIVF
 102          KM    Divert flows in excess of the Signal Butte Floodway capacity
 103          DT    DV-F
 104          DI       0    1043    1044
 105          DQ       0       0       1

 106          KK     R-F
 107          KM    Route DIVF to G
 108          RS       7    FLOW      -1
 109          RC    .035    .025    .035    3090  0.0003
 110          RX       0       1       2    21.4    41.4    60.8      61      62
 111          RY     9.7     9.7     9.7       0       0     9.7     9.7     9.7

 112          KK     S-G
 113          KM    Runoff from Sub-basin G
 114          BA    0.52
 115          LG    .300    .250   5.700    .240    15.0
 116          UC   1.030    .456

 117          KK    C-C2
 118          KM    Combine R-F and S-G
 119          HC       2

 120          KK    DIVG
 121          KM    Divert flows in excess of the Signal Butte Floodway capacity
 122          DT    DV-G
 123          DI       0    1304    1305
 124          DQ       0       0       1

 125          KK   R-G-1
 126          KM    Route DIVG to G1 - EARTHEN
 127          RS      14    FLOW      -1
 128          RC    .035    .025    .035    3943 0.00029
 129          RX       0       1       2    21.4    53.4    72.8      73      74
 130          RY     9.7     9.7     9.7       0       0     9.7     9.7     9.7

 131          KK   R-G-2
 132          KM    Route G1 to H - CONCRETE
 133          RS       2    FLOW      -1
 134          RC    .016    .016    .016    2039 0.01495
 135          RX       0       1       2     2.1    16.1    16.2      17      18
 136          RY     7.5     7.5     7.5       0       0     7.5     7.5     7.5

 137          KK     S-H
 138          KM    Runoff from Sub-basin H
 139          BA    0.86
 140          LG    .320    .250   4.400    .410    14.0
 141          UC   2.030   1.977
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 142          KK    C-C3
 143          KM    Combine R-G-2 and S-H
 144          HC       2

 145          KK    DIVH
 146          KM    Divert flows in excess of the Signal Butte Floodway capacity
 147          DT    DV-H
 148          DI       0    2777    2778
 149          DQ       0       0       1

 150          KK     R-H
 151          KM    Route DIVH to S-I
 152          RS       2    FLOW      -1
 153          RC    .016    .016    .016    3938  0.0152
 154          RX       0       1       2     2.1    16.1    16.2      17      18
 155          RY     7.5     7.5     7.5       0       0     7.5     7.5     7.5

 156          KK     S-I
 157          KM    Runoff from Sub-basin I
 158          BA    1.32
 159          LG    .300    .250   4.500    .390    15.0
 160          UC   2.010   1.752

 161          KK    C-C4
 162          KM    Combine R-H and S-I
 163          HC       2

 164          KK    DIVI
 165          KM    Divert flows in excess of the Signal Butte Floodway capacity
 166          DT    DV-I
 167          DI       0    2872    2873
 168          DQ       0       0       1

 169          KK    S-A1
 170          KM    Runoff from Sub-basin A1
 171          BA    0.96
 172          LG    .300    .260   4.250    .470    16.0
 173          UC   1.220   0.925

 174          KK    C-C5
 175          KM    Combine S-A1 and DIVI
 176          HC       2

 177          KK    S-B1
 178          KM    Runoff from Sub-basin B1
 179          BA    4.09
 180          LG    .290    .250   4.450    .410    11.0
 181          UC   1.860   1.290
 182          UA       0     3.0     5.0     8.0    12.0      20    43.0    75.0    90.0    96.0
 183          UA     100
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 184          KK    C-C6
 185          KM    Combine C-C5 and S-B1
 186          HC       2

 187          KK    S-B2
 188          KM    Runoff from Sub-basin B2
 189          BA    1.36
 190          LG    .310    .260   4.350    .460    15.0
 191          UC   1.870   1.641

 192          KK    C-C7
 193          KM    Combine C-C6 and S-B2
 194          HC       2

 195          KK    S-C1
 196          KM    Runoff from Sub-basin C1
 197          BA    2.54
 198          LG    .310    .260   4.350    .460    15.0
 199          UC   1.070   0.626
 200          UA       0     5.0    16.0    30.0    65.0      77    84.0    90.0    94.0    97.0
 201          UA     100

 202          KK    C-C8
 203          KM    Combine C-C7 and S-C1
 204          HC       2

 205          KK    S-D1
 206          KM    Runoff from Sub-basin D1
 207          BA    1.15
 208          LG    .300    .270   3.640    .670    17.0
 209          UC    .900    .649

 210          KK    C-C9
 211          KM    Combine C-C8 and S-D1
 212          HC       2

 213          KK     RES
 214          KM    Spook Hill Reservoir Routing
 215          KM    See DMJM+HARRIS Technical Report No. 1 for supporting details
 216          KM    behind rating curves.
 217          KM
 218          KM    NGVD 29 elevations used in the computations.
 219          KM
 220          KM    Sediment Storage Volume Below Principle Spillway = 271 Ac-Ft (Elev=1577.5')
 221          RS       1    STOR       0
 222          SV       0     287     346   474.9     693    1120    1631    1919    2231    2927
 223          SV    3722    4158
 224          SQ       0       0     250     500     750     990    2860    4750    7000   12750
 225          SQ   19240   23050
 226          SE  1575.1  1577.5    1578  1578.8    1580    1582    1584    1585    1586    1588
 227          SE    1590    1591
 228          ZZ
```

SCHEMATIC DIAGRAM OF STREAM NETWORK

```
INPUT
 LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

  NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

   31        S-IN
                .
                .
   87           .         S-F
                .           .
                .           .
   98        C-C1............
                .
                .
  103           .------->    DV-F
  101       DIVF
                V
                V
  106        R-F
                .
                .
  112           .         S-G
                .           .
                .           .
  117       C-C2............
                .
                .
  122           .------->    DV-G
  120       DIVG
                V
                V
  125      R-G-1
                V
                V
  131      R-G-2
                .
                .
  137           .         S-H
                .           .
                .           .
  142       C-C3............
                .
                .
  147           .------->    DV-H
  145       DIVH
                V
                V
  150        R-H
                .
                .
  156           .         S-I
                .           .
                .           .
  161       C-C4............
                .
                .
  166           .------->    DV-I
  164       DIVI
```

```
                .
                .
169             .        S-A1
                .          .
                .          .
174          C-C5............
                .
                .
177             .        S-B1
                .          .
                .          .
184          C-C6............
                .
                .
187             .        S-B2
                .          .
                .          .
192          C-C7............
                .
                .
195             .        S-C1
                .          .
                .          .
202          C-C8............
                .
                .
205             .        S-D1
                .          .
                .          .
210          C-C9............
                V
                V
213           RES
```

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

```
****************************************
*                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*              JUN   1998              *
*           VERSION 4.1                *
*                                      *
*  RUN DATE   25OCT01  TIME  11:13:39  *
*                                      *
****************************************
```

```
****************************************
*                                      *
*    U.S. ARMY CORPS OF ENGINEERS      *
*    HYDROLOGIC ENGINEERING CENTER     *
*          609 SECOND STREET           *
*        DAVIS, CALIFORNIA 95616       *
*           (916) 756-1104             *
*                                      *
****************************************
```

RED MOUNTAIN FREEWAY EXISTING HYDROLOGY ANALYSIS
POWER ROAD TO UNIVERSITY DRIVE

FILENAME: SPKHPMF.DAT

THIS MODEL REPRESENTS EXISTING CONDITIONS FOR THE CONTRIBUTING WATERSHED TO THE SPOOK HILL FRS AND THE UNCONTROLLED DRAINAGE AREA BETWEEN THE PASS MOUNTAIN DIVERSION AND THE SIGNAL BUTTE FLOODWAY. THE PROCEDURES AND GUIDELINES IN HMR 49 AND THE FCDMC HYDROLOGY MANUAL WERE USED.

HEC-1 MODEL PARAMETERS:

DRAINAGE AREA: USGS QUAD MAPS AND LANDISCOR AERIAL SURVEYS WERE USED TO IDENTIFY THE SUBBASIN BOUNDARIES AND MEASURE SUBBASIN LENGTH, SLOPE AND AREA.

HYDROGRAPH: HALF OF THE PROBABLE MAXIMUM FLOOD (0.5 PMF)

INFLOW HYDROGRAPH: THE MAXIMUM 100-YEAR, 24-HOUR STORM SIGNAL BUTTE FRS PRINCIPAL SPILLWAY OUTFLOW (157 cfs) WAS ASSUMED FOR THE UPPER CONTRIBUTING WATERSHED.

PRECIPITATION DEPTH: LOCAL PROBABLE MAXIMUM PRECIPITATION COMPUTED USING THE PROCEDURES AND GUIDELINES IN HMR 49.

RAINFALL DURATION: 6 HRS

RAINFALL DISTRIBUTION: USED THE GUIDELINES IN HMR 49.

LOSS PARAMETERS: GREEN AND AMPT AS RECOMMENDED IN THE FCDMC HYDROLOGY MANUAL (1995).

RAINFALL EXCESS TO RUNOFF TRANSFORMATION: CLARK UNIT HYDROGRAPH

CHANNEL ROUTING: NORMAL DEPTH CHANNEL ROUTING

RESERVOIR ROUTING: MODIFIED PULS RESERVOIR ROUTING

```
29 IO          OUTPUT CONTROL VARIABLES
                     IPRNT          3  PRINT CONTROL
                     IPLOT          0  PLOT CONTROL
                     QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT          HYDROGRAPH TIME DATA
                      NMIN          2  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME       0000  STARTING TIME
                        NQ        500  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      1    0  ENDING DATE
                    NDTIME       1638  ENDING TIME
                     ICENT         19  CENTURY MARK

                COMPUTATION INTERVAL     .03 HOURS
                     TOTAL TIME BASE   16.63 HOURS

        ENGLISH UNITS
```

```
            DRAINAGE AREA          SQUARE MILES
            PRECIPITATION DEPTH    INCHES
            LENGTH, ELEVATION      FEET
            FLOW                   CUBIC FEET PER SECOND
            STORAGE VOLUME         ACRE-FEET
            SURFACE AREA           ACRES
            TEMPERATURE            DEGREES FAHRENHEIT

    JP        MULTI-PLAN OPTION
                 NPLAN          1  NUMBER OF PLANS

    JR        MULTI-RATIO OPTION
                RATIOS OF RUNOFF
                .50


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 31 KK    *     S-IN   *
          *            *
          **************
                         SIGNAL BUTTE FRS INFLOW
                         SIGNAL BUTTE FRS INFLOW
                         PEAK DISCHARGE DOUBLED TO ACCOUNT FOR HALF FLOW RATIO OF JR RECORD

            SUBBASIN RUNOFF DATA

 36 BA        SUBBASIN CHARACTERISTICS
                 TAREA          .00  SUBBASIN AREA

                                                          ***

    ***          ***          ***          ***          ***

                   HYDROGRAPH AT STATION     S-IN
                     FOR PLAN 1, RATIO =  .00

PEAK FLOW    TIME                        MAXIMUM AVERAGE FLOW
  (CFS)      (HR)                 6-HR      24-HR      72-HR     16.63-HR
   314.       .80       (CFS)     314.       299.       299.        299.
                      (INCHES) 2919.423   7712.143   7712.143    7712.143
                       (AC-FT)    156.       411.       411.        411.

                     CUMULATIVE AREA =     .00 SQ MI


    ***          ***          ***          ***          ***

                   HYDROGRAPH AT STATION     S-IN
                     FOR PLAN 1, RATIO =  .50

PEAK FLOW    TIME                        MAXIMUM AVERAGE FLOW
  (CFS)      (HR)                 6-HR      24-HR      72-HR     16.63-HR
   157.       .80       (CFS)     157.       150.       150.        150.
                      (INCHES) 1459.712   3856.072   3856.072    3856.072
                       (AC-FT)     78.       206.       206.        206.
```

```
                    CUMULATIVE AREA =     .00 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 87 KK    *       S-F  *
          *            *
          **************
                    Runoff from Sub-basin F
                    HMR 49 (1977) was used to distribute the local PMP

 90 IN          TIME DATA FOR INPUT TIME SERIES
                     JXMIN          15  TIME INTERVAL IN MINUTES
                    JXDATE      1    0  STARTING DATE
                    JXTIME           0  STARTING TIME

             SUBBASIN RUNOFF DATA

 89 BA          SUBBASIN CHARACTERISTICS
                     TAREA         .15  SUBBASIN AREA

                PRECIPITATION DATA

 92 PB               STORM       12.76  BASIN TOTAL PRECIPITATION

 92 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

 96 LG          GREEN AND AMPT LOSS RATE
                    STRTL         .30  STARTING LOSS
                      DTH         .25  MOISTURE DEFICIT
                     PSIF        4.50  WETTING FRONT SUCTION
                    XKSAT         .37  HYDRAULIC CONDUCTIVITY
                    RTIMP        9.00  PERCENT IMPERVIOUS AREA

 97 UC          CLARK UNITGRAPH
                       TC        1.04  TIME OF CONCENTRATION
```

R .91 STORAGE COEFFICIENT

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 1.04 HR, R= .91 HR

SNYDER TP= .96 HR, CP= .62

UNIT HYDROGRAPH

161 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0. | 2. | 3. | 5. | 8. | 10. | 13. | 16. | 19. | 22. |
| 25. | 29. | 32. | 35. | 39. | 42. | 46. | 49. | 52. | 54. |
| 57. | 59. | 61. | 62. | 63. | 64. | 65. | 65. | 65. | 64. |
| 63. | 62. | 60. | 57. | 55. | 53. | 51. | 50. | 48. | 46. |
| 44. | 43. | 41. | 40. | 38. | 37. | 36. | 34. | 33. | 32. |
| 31. | 30. | 29. | 28. | 27. | 26. | 25. | 24. | 23. | 22. |
| 21. | 21. | 20. | 19. | 18. | 18. | 17. | 16. | 16. | 15. |
| 15. | 14. | 14. | 13. | 13. | 12. | 12. | 11. | 11. | 11. |
| 10. | 10. | 9. | 9. | 9. | 9. | 8. | 8. | 8. | 7. |
| 7. | 7. | 7. | 6. | 6. | 6. | 6. | 5. | 5. | 5. |
| 5. | 5. | 5. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 2. |
| 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 2. | 2. | 2. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1. | | | | | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-F

FOR PLAN 1, RATIO = .50

TOTAL RAINFALL = 12.76, TOTAL LOSS = 2.96, TOTAL EXCESS = 9.80

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 529. | 4.13 | (CFS) | 156. | 57. | 57. | 57. |
| | | (INCHES) | 9.679 | 9.747 | 9.747 | 9.747 |
| | | (AC-FT) | 77. | 78. | 78. | 78. |

CUMULATIVE AREA = .15 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION S-F

FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 265. | 4.13 | (CFS) | 78. | 28. | 28. | 28. |
| | | (INCHES) | 4.840 | 4.873 | 4.873 | 4.873 |
| | | (AC-FT) | 39. | 39. | 39. | 39. |

CUMULATIVE AREA = .15 SQ MI

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 98 KK    *      C-C1  *
          *            *
          **************
                         Combine S-IN and S-F

100 HC          HYDROGRAPH COMBINATION
                     ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

    ***             ***             ***             ***             ***

                       HYDROGRAPH AT STATION     C-C1
                         FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   422.       4.13       (CFS)     235.        178.        178.        178.
                       (INCHES)   14.475      30.378      30.378      30.378
                        (AC-FT)    117.        245.        245.        245.

                       CUMULATIVE AREA =     .15 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
101 KK    *      DIVF  *
          *            *
          **************
                         Divert flows in excess of the Signal Butte Floodway capacity

   DT          DIVERSION
                    ISTAD        DV-F  DIVERSION HYDROGRAPH IDENTIFICATION

   DI             INFLOW         .00   1043.00   1044.00

   DQ      DIVERTED FLOW         .00       .00      1.00

                                                          ***

    ***             ***             ***             ***             ***

                     DIVERSION HYDROGRAPH     DV-F
                       FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
     0.        .00       (CFS)       0.          0.          0.          0.
```

| | | | | |
|---|---|---|---|---|
| (INCHES) | .000 | .000 | .000 | .000 |
| (AC-FT) | 0. | 0. | 0. | 0. |

CUMULATIVE AREA = .15 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION DIVF
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 422. | 4.13 | (CFS) | 235. | 178. | 178. | 178. |
| | | (INCHES) | 14.475 | 30.378 | 30.378 | 30.378 |
| | | (AC-FT) | 117. | 245. | 245. | 245. |

CUMULATIVE AREA = .15 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
106 KK    *      R-F   *
          *            *
          **************
```

Route DIVF to G

HYDROGRAPH ROUTING DATA

```
108 RS        STORAGE ROUTING
                   NSTPS          7  NUMBER OF SUBREACHES
                    ITYP       FLOW  TYPE OF INITIAL CONDITION
                  RSVRIC      -1.00  INITIAL CONDITION
                       X        .00 WORKING R AND D COEFFICIENT

109 RC        NORMAL DEPTH CHANNEL
                     ANL       .035  LEFT OVERBANK N-VALUE
                    ANCH       .025  MAIN CHANNEL N-VALUE
                     ANR       .035  RIGHT OVERBANK N-VALUE
                   RLNTH      3090.  REACH LENGTH
                     SEL      .0003  ENERGY SLOPE
                   ELMAX         .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION
```

CROSS-SECTION DATA

| | | --- LEFT OVERBANK --- | | | + ------ MAIN CHANNEL ------- | | + --- RIGHT OVERBANK --- | | |
|---|---|---|---|---|---|---|---|---|---|
| 111 RY | ELEVATION | 9.70 | 9.70 | 9.70 | .00 | .00 | 9.70 | 9.70 | 9.70 |
| 110 RX | DISTANCE | .00 | 1.00 | 2.00 | 21.40 | 41.40 | 60.80 | 61.00 | 62.00 |

***

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | .00 | .76 | 1.60 | 2.51 | 3.49 | 4.55 | 5.68 | 6.88 | 8.16 | 9.51 |
| OUTFLOW | .00 | 6.81 | 21.92 | 43.78 | 71.98 | 106.41 | 147.05 | 194.01 | 247.39 | 307.35 |
| ELEVATION | .00 | .51 | 1.02 | 1.53 | 2.04 | 2.55 | 3.06 | 3.57 | 4.08 | 4.59 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | 10.94 | 12.44 | 14.02 | 15.67 | 17.39 | 19.18 | 21.06 | 23.00 | 25.02 | 27.11 |
| OUTFLOW | 374.05 | 447.65 | 528.33 | 616.29 | 711.70 | 814.74 | 925.61 | 1044.49 | 1171.57 | 1307.03 |
| ELEVATION | 5.11 | 5.62 | 6.13 | 6.64 | 7.15 | 7.66 | 8.17 | 8.68 | 9.19 | 9.70 |

*** *** *** *** ***

HYDROGRAPH AT STATION R-F
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 417. | 4.37 | (CFS) | 235. | 174. | 174. | 174. |
| | | (INCHES) | 14.474 | 29.641 | 29.641 | 29.641 |
| | | (AC-FT) | 117. | 239. | 239. | 239. |

| PEAK STORAGE (AC-FT) | TIME (HR) | MAXIMUM AVERAGE STORAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 2. | 4.37 | 1. | 1. | 1. | 1. |

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 5.40 | 4.37 | 3.90 | 3.21 | 3.21 | 3.21 |

CUMULATIVE AREA = .15 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
112 KK    *      S-G   *
          *            *
          **************
```

Runoff from Sub-basin G

SUBBASIN RUNOFF DATA

114 BA SUBBASIN CHARACTERISTICS
TAREA .52 SUBBASIN AREA

PRECIPITATION DATA

92 PB STORM 12.76 BASIN TOTAL PRECIPITATION

92 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

```
115 LG          GREEN AND AMPT LOSS RATE
                     STRTL        .30  STARTING LOSS
                       DTH        .25  MOISTURE DEFICIT
                      PSIF       5.70  WETTING FRONT SUCTION
                     XKSAT        .24  HYDRAULIC CONDUCTIVITY
                     RTIMP      15.00  PERCENT IMPERVIOUS AREA

116 UC          CLARK UNITGRAPH
                        TC       1.03  TIME OF CONCENTRATION
                         R        .46  STORAGE COEFFICIENT

                SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                    ***

                                          UNIT HYDROGRAPH PARAMETERS
                                   CLARK   TC=  1.03 HR,       R=   .46 HR
                                  SNYDER   TP=   .84 HR,      CP=   .77

                                            UNIT HYDROGRAPH
                                        90 END-OF-PERIOD ORDINATES
          3.      11.      22.      36.      51.      67.      84.     101.     119.     137.
        155.     173.     191.     209.     227.     245.     261.     276.     288.     298.
        306.     312.     316.     318.     319.     317.     314.     310.     303.     293.
        280.     263.     244.     227.     211.     196.     182.     170.     158.     146.
        136.     127.     118.     109.     102.      94.      88.      82.      76.      70.
         66.      61.      57.      53.      49.      45.      42.      39.      36.      34.
         32.      29.      27.      25.      24.      22.      20.      19.      18.      16.
         15.      14.      13.      12.      11.      11.      10.       9.       8.       8.
          7.       7.       6.       6.       5.       5.       5.       4.       4.       4.

   ***          ***          ***          ***          ***

                  HYDROGRAPH AT STATION      S-G
                    FOR PLAN 1, RATIO =  .50

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    2.37, TOTAL EXCESS =   10.39

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  2580.       4.03        (CFS)     576.        208.        208.        208.
                        (INCHES)  10.305      10.334      10.334      10.334
                         (AC-FT)    286.        287.        287.        287.

                  CUMULATIVE AREA =     .52 SQ MI

   ***          ***          ***          ***          ***

                  HYDROGRAPH AT STATION      S-G
                    FOR PLAN 1, RATIO =  .50
```

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1290. | 4.03 | (CFS) | 288. | 104. | 104. | 104. |
| | | (INCHES) | 5.152 | 5.167 | 5.167 | 5.167 |
| | | (AC-FT) | 143. | 143. | 143. | 143. |

CUMULATIVE AREA = .52 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
117 KK    *      C-C2  *
          *            *
          **************
```

Combine R-F and S-G

119 HC HYDROGRAPH COMBINATION

ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

*** *** *** *** ***

HYDROGRAPH AT STATION C-C2
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1650. | 4.07 | (CFS) | 522. | 278. | 278. | 278. |
| | | (INCHES) | 7.230 | 10.675 | 10.675 | 10.675 |
| | | (AC-FT) | 259. | 382. | 382. | 382. |

CUMULATIVE AREA = .67 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
120 KK    *      DIVG  *
          *            *
          **************
```

Divert flows in excess of the Signal Butte Floodway capacity

DT DIVERSION

ISTAD DV-G DIVERSION HYDROGRAPH IDENTIFICATION

| | | | | |
|---|---|---|---|---|
| DI | INFLOW | .00 | 1304.00 | 1305.00 |
| DQ | DIVERTED FLOW | .00 | .00 | 1.00 |

***

*** *** *** *** ***

DIVERSION HYDROGRAPH DV-G
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 346. | 4.07 | (CFS) | 25. | 9. | 9. | 9. |
| | | (INCHES) | .351 | .351 | .351 | .351 |
| | | (AC-FT) | 13. | 13. | 13. | 13. |

CUMULATIVE AREA = .67 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION DIVG
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1304. | 3.73 | (CFS) | 496. | 269. | 269. | 269. |
| | | (INCHES) | 6.879 | 10.323 | 10.323 | 10.323 |
| | | (AC-FT) | 246. | 369. | 369. | 369. |

CUMULATIVE AREA = .67 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
125 KK    *     R-G-1  *
          *            *
          **************
```

Route DIVG to G1 - EARTHEN

HYDROGRAPH ROUTING DATA

```
127 RS        STORAGE ROUTING
                   NSTPS          14  NUMBER OF SUBREACHES
                    ITYP        FLOW  TYPE OF INITIAL CONDITION
                  RSVRIC       -1.00  INITIAL CONDITION
                       X         .00 WORKING R AND D COEFFICIENT

128 RC        NORMAL DEPTH CHANNEL
                     ANL        .035  LEFT OVERBANK N-VALUE
                    ANCH        .025  MAIN CHANNEL N-VALUE
                     ANR        .035  RIGHT OVERBANK N-VALUE
                   RLNTH       3943.  REACH LENGTH
                     SEL       .0003  ENERGY SLOPE
                   ELMAX          .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION
```

CROSS-SECTION DATA

--- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 130 RY | ELEVATION | 9.70 | 9.70 | 9.70 | .00 | .00 | 9.70 | 9.70 | 9.70 |
| 129 RX | DISTANCE | .00 | 1.00 | 2.00 | 21.40 | 53.40 | 72.80 | 73.00 | 74.00 |

***

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | .00 | 1.53 | 3.15 | 4.86 | 6.67 | 8.57 | 10.57 | 12.66 | 14.85 | 17.13 |
| OUTFLOW | .00 | 10.66 | 34.11 | 67.64 | 110.32 | 161.70 | 221.56 | 289.79 | 366.37 | 451.32 |
| ELEVATION | .00 | .51 | 1.02 | 1.53 | 2.04 | 2.55 | 3.06 | 3.57 | 4.08 | 4.59 |
| STORAGE | 19.51 | 21.98 | 24.54 | 27.20 | 29.95 | 32.80 | 35.74 | 38.78 | 41.91 | 45.13 |
| OUTFLOW | 544.70 | 646.60 | 757.12 | 876.38 | 1004.50 | 1141.63 | 1287.91 | 1443.47 | 1608.47 | 1783.06 |
| ELEVATION | 5.11 | 5.62 | 6.13 | 6.64 | 7.15 | 7.66 | 8.17 | 8.68 | 9.19 | 9.70 |

*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN 1443. TO 1783.
THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

*** *** *** *** ***

HYDROGRAPH AT STATION R-G-1
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1304. | 4.20 | (CFS) | 496. | 263. | 263. | 263. |
| | | (INCHES) | 6.879 | 10.089 | 10.089 | 10.089 |
| | | (AC-FT) | 246. | 361. | 361. | 361. |

| PEAK STORAGE (AC-FT) | TIME (HR) | MAXIMUM AVERAGE STORAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 3. | 4.17 | 1. | 1. | 1. | 1. |

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 8.22 | 4.23 | 4.47 | 2.95 | 2.95 | 2.95 |

CUMULATIVE AREA = .67 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
              **************
              *            *
131 KK        *     R-G-2  *
              *            *
              **************
```

Route G1 to H - CONCRETE

HYDROGRAPH ROUTING DATA

| | | | |
|---|---|---|---|
| 133 RS | STORAGE ROUTING | | |
| | NSTPS | 2 | NUMBER OF SUBREACHES |
| | ITYP | FLOW | TYPE OF INITIAL CONDITION |
| | RSVRIC | -1.00 | INITIAL CONDITION |

```
                    X          .00 WORKING R AND D COEFFICIENT

 134 RC          NORMAL DEPTH CHANNEL
                        ANL        .016  LEFT OVERBANK N-VALUE
                       ANCH        .016  MAIN CHANNEL N-VALUE
                        ANR        .016  RIGHT OVERBANK N-VALUE
                      RLNTH       2039.  REACH LENGTH
                        SEL       .0149  ENERGY SLOPE
                      ELMAX          .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION

                                   CROSS-SECTION DATA
                        --- LEFT OVERBANK --- + ------ MAIN CHANNEL ------- + --- RIGHT OVERBANK ---
 136 RY       ELEVATION     7.50      7.50      7.50       .00       .00      7.50      7.50      7.50
 135 RX       DISTANCE       .00      1.00      2.00      2.10     16.10     16.20     17.00     18.00

                                                  ***

                                   COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

          STORAGE       .00       .26       .52       .78      1.04      1.30      1.56      1.82      2.08      2.34
          OUTFLOW       .00     32.66    100.23    190.75    298.76    420.81    554.45    697.84    849.58   1008.54
        ELEVATION       .00       .39       .79      1.18      1.58      1.97      2.37      2.76      3.16      3.55

          STORAGE      2.60      2.86      3.12      3.38      3.64      3.90      4.16      4.43      4.69      4.95
          OUTFLOW   1173.80   1344.61   1520.34   1700.48   1884.57   2072.23   2263.13   2456.99   2653.56   2852.61
        ELEVATION      3.95      4.34      4.74      5.13      5.53      5.92      6.32      6.71      7.11      7.50


*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN      191. TO     2853.
               THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
               THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION    R-G-2
                         FOR PLAN 1, RATIO =  .50

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                   6-HR       24-HR       72-HR     16.63-HR
    1304.      4.20        (CFS)      496.        262.        262.        262.
                         (INCHES)    6.879      10.070      10.070      10.070
                          (AC-FT)    246.        360.        360.        360.

PEAK STORAGE   TIME                          MAXIMUM AVERAGE STORAGE
  (AC-FT)      (HR)                   6-HR       24-HR       72-HR     16.63-HR
       1.      4.13                     1.         0.          0.          0.

 PEAK STAGE    TIME                          MAXIMUM AVERAGE STAGE
   (FEET)      (HR)                   6-HR       24-HR       72-HR     16.63-HR
     4.25      4.27                   2.08       1.30        1.30        1.30

                         CUMULATIVE AREA =     .67 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          ***************
```

```
          *           *
137 KK    *      S-H  *
          *           *
          **************
                    Runoff from Sub-basin H

        SUBBASIN RUNOFF DATA

139 BA        SUBBASIN CHARACTERISTICS
                  TAREA          .86  SUBBASIN AREA

              PRECIPITATION DATA

 92 PB            STORM        12.76  BASIN TOTAL PRECIPITATION

 92 PI          INCREMENTAL PRECIPITATION PATTERN
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                  .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                  .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

140 LG        GREEN AND AMPT LOSS RATE
                  STRTL          .32  STARTING LOSS
                    DTH          .25  MOISTURE DEFICIT
                   PSIF         4.40  WETTING FRONT SUCTION
                  XKSAT          .41  HYDRAULIC CONDUCTIVITY
                  RTIMP        14.00  PERCENT IMPERVIOUS AREA

141 UC        CLARK UNITGRAPH
                     TC         2.03  TIME OF CONCENTRATION
                      R         1.98  STORAGE COEFFICIENT

              SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                          ***

                                   UNIT HYDROGRAPH PARAMETERS
                             CLARK   TC=  2.03 HR,       R=  1.98 HR
                            SNYDER   TP=  1.91 HR,      CP=   .59

                                   UNIT HYDROGRAPH
                              300 END-OF-PERIOD ORDINATES
                                     VOLUME =  .99
          0.       2.       3.       5.       8.      10.      13.      16.      20.      23.
         27.      30.      34.      38.      42.      46.      50.      55.      59.      63.
         68.      72.      77.      82.      86.      91.      96.     101.     106.     111.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 116. | 120. | 125. | 130. | 134. | 138. | 142. | 146. | 149. | 152. |
| 155. | 158. | 161. | 164. | 166. | 168. | 170. | 172. | 174. | 175. |
| 176. | 177. | 178. | 178. | 179. | 179. | 178. | 178. | 177. | 176. |
| 174. | 171. | 169. | 166. | 163. | 160. | 158. | 155. | 152. | 150. |
| 147. | 145. | 142. | 140. | 138. | 135. | 133. | 131. | 129. | 127. |
| 124. | 122. | 120. | 118. | 116. | 114. | 112. | 111. | 109. | 107. |
| 105. | 103. | 102. | 100. | 98. | 97. | 95. | 93. | 92. | 90. |
| 89. | 87. | 86. | 84. | 83. | 82. | 80. | 79. | 78. | 76. |
| 75. | 74. | 73. | 71. | 70. | 69. | 68. | 67. | 66. | 64. |
| 63. | 62. | 61. | 60. | 59. | 58. | 57. | 56. | 55. | 54. |
| 54. | 53. | 52. | 51. | 50. | 49. | 48. | 48. | 47. | 46. |
| 45. | 44. | 44. | 43. | 42. | 42. | 41. | 40. | 40. | 39. |
| 38. | 38. | 37. | 36. | 36. | 35. | 35. | 34. | 33. | 33. |
| 32. | 32. | 31. | 31. | 30. | 30. | 29. | 29. | 28. | 28. |
| 27. | 27. | 26. | 26. | 25. | 25. | 25. | 24. | 24. | 23. |
| 23. | 23. | 22. | 22. | 22. | 21. | 21. | 20. | 20. | 20. |
| 19. | 19. | 19. | 19. | 18. | 18. | 18. | 17. | 17. | 17. |
| 16. | 16. | 16. | 16. | 15. | 15. | 15. | 15. | 14. | 14. |
| 14. | 14. | 13. | 13. | 13. | 13. | 13. | 12. | 12. | 12. |
| 12. | 12. | 11. | 11. | 11. | 11. | 11. | 10. | 10. | 10. |
| 10. | 10. | 10. | 9. | 9. | 9. | 9. | 9. | 9. | 9. |
| 8. | 8. | 8. | 8. | 8. | 8. | 8. | 7. | 7. | 7. |
| 7. | 7. | 7. | 7. | 7. | 7. | 6. | 6. | 6. | 6. |
| 6. | 6. | 6. | 6. | 6. | 5. | 5. | 5. | 5. | 5. |
| 5. | 5. | 5. | 5. | 5. | 5. | 5. | 4. | 4. | 4. |
| 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. | 4. |
| 4. | 4. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |

*** *** *** *** ***

HYDROGRAPH AT STATION S-H
FOR PLAN 1, RATIO = .50

TOTAL RAINFALL = 12.76, TOTAL LOSS = 2.94, TOTAL EXCESS = 9.82

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1626. | 5.03 | (CFS) | 825. | 324. | 324. | 324. |
| | | (INCHES) | 8.924 | 9.709 | 9.709 | 9.709 |
| | | (AC-FT) | 409. | 445. | 445. | 445. |

CUMULATIVE AREA = .86 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION S-H
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 813. | 5.03 | (CFS) | 413. | 162. | 162. | 162. |
| | | (INCHES) | 4.462 | 4.854 | 4.854 | 4.854 |
| | | (AC-FT) | 205. | 223. | 223. | 223. |

CUMULATIVE AREA = .86 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
142 KK    *      C-C3  *
          *            *
          **************
                         Combine R-G-2 and S-H

144 HC          HYDROGRAPH COMBINATION
                     ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION     C-C3
                        FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
   2030.      4.67       (CFS)      904.        424.        424.        424.
                       (INCHES)    5.493       7.140       7.140       7.140
                        (AC-FT)    449.        583.        583.        583.

                       CUMULATIVE AREA =    1.53 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
145 KK    *      DIVH  *
          *            *
          **************
                         Divert flows in excess of the Signal Butte Floodway capacity

   DT          DIVERSION
                     ISTAD        DV-H  DIVERSION HYDROGRAPH IDENTIFICATION

   DI             INFLOW         .00   2777.00   2778.00

   DQ      DIVERTED FLOW         .00       .00      1.00

                                                          ***

    ***            ***            ***            ***            ***

                      DIVERSION HYDROGRAPH     DV-H
                        FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
      0.       .00       (CFS)        0.          0.          0.          0.
                       (INCHES)     .000        .000        .000        .000
                        (AC-FT)       0.          0.          0.          0.
```

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION DIVH
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2030. | 4.67 | (CFS) | 904. | 424. | 424. | 424. |
| | | (INCHES) | 5.493 | 7.140 | 7.140 | 7.140 |
| | | (AC-FT) | 449. | 583. | 583. | 583. |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
150 KK    *       R-H  *
          *            *
          **************
```

Route DIVH to S-I

HYDROGRAPH ROUTING DATA

```
152 RS        STORAGE ROUTING
                   NSTPS          2  NUMBER OF SUBREACHES
                   ITYP       FLOW  TYPE OF INITIAL CONDITION
                  RSVRIC      -1.00  INITIAL CONDITION
                       X        .00 WORKING R AND D COEFFICIENT

153 RC        NORMAL DEPTH CHANNEL
                     ANL       .016  LEFT OVERBANK N-VALUE
                    ANCH       .016  MAIN CHANNEL N-VALUE
                     ANR       .016  RIGHT OVERBANK N-VALUE
                   RLNTH      3938.  REACH LENGTH
                     SEL      .0152  ENERGY SLOPE
                   ELMAX         .0  MAX. ELEV. FOR STORAGE/OUTFLOW CALCULATION
```

CROSS-SECTION DATA

| | | --- LEFT OVERBANK --- | | | + ------ MAIN CHANNEL ------- | | + --- RIGHT OVERBANK --- | | |
|---|---|---|---|---|---|---|---|---|---|
| 155 RY | ELEVATION | 7.50 | 7.50 | 7.50 | .00 | .00 | 7.50 | 7.50 | 7.50 |
| 154 RX | DISTANCE | .00 | 1.00 | 2.00 | 2.10 | 16.10 | 16.20 | 17.00 | 18.00 |

***

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STORAGE | .00 | .50 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 3.51 | 4.01 | 4.51 |
| OUTFLOW | .00 | 32.94 | 101.07 | 192.33 | 301.25 | 424.31 | 559.06 | 703.65 | 856.66 | 1016.94 |
| ELEVATION | .00 | .39 | .79 | 1.18 | 1.58 | 1.97 | 2.37 | 2.76 | 3.16 | 3.55 |
| STORAGE | 5.01 | 5.52 | 6.02 | 6.53 | 7.03 | 7.54 | 8.04 | 8.55 | 9.05 | 9.56 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| OUTFLOW | 1183.57 | 1355.80 | 1533.00 | 1714.64 | 1900.26 | 2089.49 | 2281.98 | 2477.45 | 2675.65 | 2876.36 |
| ELEVATION | 3.95 | 4.34 | 4.74 | 5.13 | 5.53 | 5.92 | 6.32 | 6.71 | 7.11 | 7.50 |

*** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN 1715. TO 2876.
THE ROUTED HYDROGRAPH SHOULD BE EXAMINED FOR OSCILLATIONS OR OUTFLOWS GREATER THAN PEAK INFLOWS.
THIS CAN BE CORRECTED BY DECREASING THE TIME INTERVAL OR INCREASING STORAGE (USE A LONGER REACH.)

*** *** *** *** ***

HYDROGRAPH AT STATION R-H
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2028. | 4.70 | (CFS) | 904. | 423. | 423. | 423. |
| | | (INCHES) | 5.492 | 7.124 | 7.124 | 7.124 |
| | | (AC-FT) | 448. | 582. | 582. | 582. |

| PEAK STORAGE (AC-FT) | TIME (HR) | MAXIMUM AVERAGE STORAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 4. | 4.67 | 2. | 1. | 1. | 1. |

| PEAK STAGE (FEET) | TIME (HR) | MAXIMUM AVERAGE STAGE 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|
| 5.79 | 4.70 | 3.16 | 1.74 | 1.74 | 1.74 |

CUMULATIVE AREA = 1.53 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
**************
*            *
*      S-I   *
*            *
**************
```

156 KK

Runoff from Sub-basin I

SUBBASIN RUNOFF DATA

158 BA SUBBASIN CHARACTERISTICS
TAREA 1.32 SUBBASIN AREA

PRECIPITATION DATA

92 PB STORM 12.76 BASIN TOTAL PRECIPITATION

92 PI INCREMENTAL PRECIPITATION PATTERN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

159 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .30 | STARTING LOSS |
| DTH | .25 | MOISTURE DEFICIT |
| PSIF | 4.50 | WETTING FRONT SUCTION |
| XKSAT | .39 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 15.00 | PERCENT IMPERVIOUS AREA |

160 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | 2.01 | TIME OF CONCENTRATION |
| R | 1.75 | STORAGE COEFFICIENT |

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= 2.01 HR, R= 1.75 HR

SNYDER TP= 1.87 HR, CP= .62

UNIT HYDROGRAPH

300 END-OF-PERIOD ORDINATES

VOLUME = .99

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 3. | 6. | 9. | 14. | 18. | 23. | 29. | 34. | 40. |
| 46. | 53. | 59. | 66. | 73. | 80. | 87. | 94. | 102. | 110. |
| 117. | 125. | 133. | 141. | 149. | 157. | 165. | 173. | 182. | 190. |
| 198. | 206. | 214. | 221. | 228. | 235. | 241. | 247. | 253. | 258. |
| 263. | 268. | 272. | 276. | 280. | 283. | 286. | 289. | 291. | 293. |
| 294. | 295. | 296. | 296. | 296. | 296. | 294. | 293. | 291. | 288. |
| 283. | 278. | 273. | 268. | 263. | 258. | 253. | 248. | 243. | 239. |
| 234. | 230. | 226. | 221. | 217. | 213. | 209. | 205. | 201. | 197. |
| 194. | 190. | 186. | 183. | 179. | 176. | 173. | 170. | 166. | 163. |
| 160. | 157. | 154. | 151. | 148. | 146. | 143. | 140. | 138. | 135. |
| 132. | 130. | 127. | 125. | 123. | 120. | 118. | 116. | 114. | 112. |
| 109. | 107. | 105. | 103. | 101. | 100. | 98. | 96. | 94. | 92. |
| 90. | 89. | 87. | 85. | 84. | 82. | 81. | 79. | 78. | 76. |
| 75. | 73. | 72. | 71. | 69. | 68. | 67. | 65. | 64. | 63. |
| 62. | 61. | 60. | 58. | 57. | 56. | 55. | 54. | 53. | 52. |
| 51. | 50. | 49. | 48. | 47. | 46. | 46. | 45. | 44. | 43. |
| 42. | 41. | 41. | 40. | 39. | 38. | 38. | 37. | 36. | 36. |
| 35. | 34. | 34. | 33. | 32. | 32. | 31. | 31. | 30. | 29. |
| 29. | 28. | 28. | 27. | 27. | 26. | 26. | 25. | 25. | 24. |
| 24. | 23. | 23. | 23. | 22. | 22. | 21. | 21. | 21. | 20. |
| 20. | 19. | 19. | 19. | 18. | 18. | 18. | 17. | 17. | 17. |
| 16. | 16. | 16. | 15. | 15. | 15. | 15. | 14. | 14. | 14. |
| 13. | 13. | 13. | 13. | 13. | 12. | 12. | 12. | 12. | 11. |
| 11. | 11. | 11. | 11. | 10. | 10. | 10. | 10. | 10. | 9. |
| 9. | 9. | 9. | 9. | 9. | 8. | 8. | 8. | 8. | 8. |
| 8. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 7. | 6. |
| 6. | 6. | 6. | 6. | 6. | 6. | 6. | 6. | 5. | 5. |

```
          5.      5.      5.      5.      5.      5.      5.      5.      4.      4.
          4.      4.      4.      4.      4.      4.      4.      4.      4.      4.
          4.      3.      3.      3.      3.      3.      3.      3.      3.      3.

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION      S-I
                     FOR PLAN 1, RATIO =  .50

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    2.84, TOTAL EXCESS =    9.92

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  2706.       5.00       (CFS)      1308.       505.        505.        505.
                       (INCHES)     9.211      9.857       9.857       9.857
                        (AC-FT)     648.        694.        694.        694.

                     CUMULATIVE AREA =    1.32 SQ MI


   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION      S-I
                     FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  1353.       5.00       (CFS)      654.        252.        252.        252.
                       (INCHES)     4.606      4.929       4.929       4.929
                        (AC-FT)     324.        347.        347.        347.

                     CUMULATIVE AREA =    1.32 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
161 KK    *      C-C4  *
          *            *
          **************
                    Combine R-H and S-I

163 HC          HYDROGRAPH COMBINATION
                     ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

   ***          ***          ***          ***          ***

                    HYDROGRAPH AT STATION     C-C4
                     FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  3311.       4.73       (CFS)      1558.       676.        676.        676.
                       (INCHES)     5.082      6.108       6.108       6.108
```

| | | | | |
|---|---|---|---|---|
| (AC-FT) | 773. | 929. | 929. | 929. |

CUMULATIVE AREA = 2.85 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
164 KK    *      DIVI  *
          *            *
          **************
```

Divert flows in excess of the Signal Butte Floodway capacity

| DT | DIVERSION ISTAD | DV-I | DIVERSION HYDROGRAPH IDENTIFICATION | |
|---|---|---|---|---|
| DI | INFLOW | .00 | 2872.00 | 2873.00 |
| DQ | DIVERTED FLOW | .00 | .00 | 1.00 |

***

*** *** *** *** ***

DIVERSION HYDROGRAPH DV-I
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | 6-HR | MAXIMUM AVERAGE FLOW 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 439. | 4.73 | (CFS) | 41. | 15. | 15. | 15. |
| | | (INCHES) | .134 | .134 | .134 | .134 |
| | | (AC-FT) | 20. | 20. | 20. | 20. |

CUMULATIVE AREA = 2.85 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION DIVI
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | 6-HR | MAXIMUM AVERAGE FLOW 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2872. | 4.33 | (CFS) | 1517. | 661. | 661. | 661. |
| | | (INCHES) | 4.948 | 5.974 | 5.974 | 5.974 |
| | | (AC-FT) | 752. | 908. | 908. | 908. |

CUMULATIVE AREA = 2.85 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

**********

```
          *           *
169 KK    *     S-A1  *
          *           *
          **************
                    Runoff from Sub-basin A1

            SUBBASIN RUNOFF DATA

171 BA        SUBBASIN CHARACTERISTICS
                  TAREA          .96  SUBBASIN AREA

              PRECIPITATION DATA

 92 PB            STORM        12.76  BASIN TOTAL PRECIPITATION

 92 PI          INCREMENTAL PRECIPITATION PATTERN
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                  .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                  .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                  .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

172 LG        GREEN AND AMPT LOSS RATE
                  STRTL          .30  STARTING LOSS
                    DTH          .26  MOISTURE DEFICIT
                   PSIF         4.25  WETTING FRONT SUCTION
                  XKSAT          .47  HYDRAULIC CONDUCTIVITY
                  RTIMP        16.00  PERCENT IMPERVIOUS AREA

173 UC        CLARK UNITGRAPH
                     TC         1.22  TIME OF CONCENTRATION
                      R          .93  STORAGE COEFFICIENT

              SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                                  ***

                                        UNIT HYDROGRAPH PARAMETERS
                                  CLARK   TC=  1.22 HR,      R=   .93 HR
                                 SNYDER   TP=  1.11 HR,     CP=   .66

                                          UNIT HYDROGRAPH
                                     167 END-OF-PERIOD ORDINATES
          2.       8.      17.      27.      38.      51.      65.      79.      94.     110.
        126.     142.     159.     176.     193.     211.     229.     247.     264.     281.
        297.     312.     325.     336.     347.     356.     364.     371.     376.     380.
        383.     384.     384.     382.     379.     373.     364.     352.     340.     328.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 316. | 305. | 294. | 284. | 274. | 264. | 255. | 246. | 237. | 229. |
| 221. | 213. | 205. | 198. | 191. | 184. | 178. | 171. | 165. | 159. |
| 154. | 148. | 143. | 138. | 133. | 128. | 124. | 120. | 115. | 111. |
| 107. | 103. | 100. | 96. | 93. | 90. | 86. | 83. | 80. | 78. |
| 75. | 72. | 70. | 67. | 65. | 62. | 60. | 58. | 56. | 54. |
| 52. | 50. | 49. | 47. | 45. | 44. | 42. | 41. | 39. | 38. |
| 36. | 35. | 34. | 33. | 32. | 30. | 29. | 28. | 27. | 26. |
| 25. | 24. | 24. | 23. | 22. | 21. | 20. | 20. | 19. | 18. |
| 18. | 17. | 16. | 16. | 15. | 15. | 14. | 14. | 13. | 13. |
| 12. | 12. | 11. | 11. | 11. | 10. | 10. | 10. | 9. | 9. |
| 9. | 8. | 8. | 8. | 7. | 7. | 7. | 7. | 6. | 6. |
| 6. | 6. | 6. | 5. | 5. | 5. | 5. | 5. | 4. | 4. |
| 4. | 4. | 4. | 4. | 4. | 3. | 3. | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-A1
FOR PLAN 1, RATIO = .50

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.08, TOTAL EXCESS = 9.68

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 3197. | 4.27 | (CFS) | 984. | 359. | 359. | 359. |
| | | (INCHES) | 9.527 | 9.634 | 9.634 | 9.634 |
| | | (AC-FT) | 488. | 493. | 493. | 493. |

CUMULATIVE AREA = .96 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION S-A1
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1598. | 4.27 | (CFS) | 492. | 179. | 179. | 179. |
| | | (INCHES) | 4.763 | 4.817 | 4.817 | 4.817 |
| | | (AC-FT) | 244. | 247. | 247. | 247. |

CUMULATIVE AREA = .96 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
174 KK    *      C-C5  *
          *            *
          **************
```

Combine S-A1 and DIVI

176 HC HYDROGRAPH COMBINATION
ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

```
***          ***          ***          ***          ***

                HYDROGRAPH AT STATION     C-C5
                  FOR PLAN 1, RATIO =  .50

PEAK FLOW    TIME                        MAXIMUM AVERAGE FLOW
  (CFS)      (HR)                6-HR       24-HR       72-HR     16.63-HR
   4457.     4.33      (CFS)     2002.       840.        840.        840.
                     (INCHES)    4.885      5.682       5.682       5.682
                      (AC-FT)    993.       1155.       1155.       1155.

                    CUMULATIVE AREA =    3.81 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
177 KK    *     S-B1   *
          *            *
          **************
                    Runoff from Sub-basin B1

            SUBBASIN RUNOFF DATA

179 BA          SUBBASIN CHARACTERISTICS
                      TAREA        4.09  SUBBASIN AREA

                PRECIPITATION DATA

 92 PB                STORM       12.76  BASIN TOTAL PRECIPITATION

 92 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .06      .06      .06      .06      .06      .06      .06      .04      .02      .02
                     .02      .02      .02      .02      .02      .01      .01      .01      .01      .01
                     .01      .01      .01      .01      .01      .01      .01      .01      .01      .01
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                     .00      .00      .00      .00      .00      .00      .00      .00      .00      .00

180 LG          GREEN AND AMPT LOSS RATE
                      STRTL         .29  STARTING LOSS
                        DTH         .25  MOISTURE DEFICIT
                       PSIF        4.45  WETTING FRONT SUCTION
```

```
                XKSAT        .41  HYDRAULIC CONDUCTIVITY
                RTIMP      11.00  PERCENT IMPERVIOUS AREA

181 UC        CLARK UNITGRAPH
                  TC        1.86  TIME OF CONCENTRATION
                   R        1.29  STORAGE COEFFICIENT

182 UA        ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                 .0       3.0       5.0       8.0      12.0      20.0      43.0      75.0      90.0      96.0
               100.0

                                                  ***

                                          UNIT HYDROGRAPH PARAMETERS
                                     CLARK   TC=  1.86 HR,       R=  1.29 HR
                                    SNYDER   TP=  1.56 HR,      CP=   .76

                                          UNIT HYDROGRAPH
                                     240 END-OF-PERIOD ORDINATES
          5.       16.       27.       37.       47.       56.       62.       68.       74.       79.
         84.       91.       99.      107.      116.      123.      132.      141.      152.      163.
        173.      183.      198.      220.      243.      266.      288.      312.      363.      437.
        509.      579.      648.      723.      813.      908.     1000.     1091.     1179.     1236.
       1260.     1282.     1304.     1325.     1340.     1338.     1325.     1313.     1301.     1290.
       1276.     1259.     1241.     1224.     1207.     1189.     1165.     1135.     1106.     1078.
       1050.     1024.      997.      972.      947.      923.      900.      877.      854.      832.
        811.      791.      770.      751.      732.      713.      695.      677.      660.      643.
        626.      610.      595.      580.      565.      551.      536.      523.      509.      496.
        484.      471.      459.      448.      436.      425.      414.      404.      393.      383.
        374.      364.      355.      346.      337.      328.      320.      312.      304.      296.
        289.      281.      274.      267.      260.      254.      247.      241.      235.      229.
        223.      217.      212.      206.      201.      196.      191.      186.      181.      177.
        172.      168.      163.      159.      155.      151.      147.      144.      140.      136.
        133.      130.      126.      123.      120.      117.      114.      111.      108.      105.
        103.      100.       97.       95.       93.       90.       88.       86.       83.       81.
         79.       77.       75.       73.       71.       70.       68.       66.       64.       63.
         61.       60.       58.       57.       55.       54.       52.       51.       50.       49.
         47.       46.       45.       44.       43.       42.       40.       39.       38.       37.
         37.       36.       35.       34.       33.       32.       31.       30.       30.       29.
         28.       27.       27.       26.       25.       25.       24.       24.       23.       22.
         22.       21.       21.       20.       20.       19.       19.       18.       18.       17.
         17.       16.       16.       16.       15.       15.       14.       14.       14.       13.
         13.       13.       12.       12.       12.       11.       11.       11.       11.       10.

   ***          ***          ***          ***          ***

                  HYDROGRAPH AT STATION     S-B1
                   FOR PLAN 1, RATIO =  .50

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    3.04, TOTAL EXCESS =    9.72

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
  11044.      4.83        (CFS)    4137.       1535.       1535.       1535.
                        (INCHES)   9.403       9.672       9.672       9.672
                         (AC-FT)   2051.       2110.       2110.       2110.

                       CUMULATIVE AREA =    4.09 SQ MI
```

```
***            ***            ***            ***            ***

                    HYDROGRAPH AT STATION     S-B1
                      FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   5522.      4.83       (CFS)     2068.       767.        767.        767.
                       (INCHES)    4.702      4.836       4.836       4.836
                        (AC-FT)    1026.      1055.       1055.       1055.

                      CUMULATIVE AREA =    4.09 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
184 KK    *      C-C6  *
          *            *
          **************
                         Combine C-C5 and S-B1

186 HC          HYDROGRAPH COMBINATION
                     ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

***            ***            ***            ***            ***

                    HYDROGRAPH AT STATION     C-C6
                      FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
   9597.      4.73       (CFS)     4070.      1608.       1608.       1608.
                       (INCHES)    4.790      5.244       5.244       5.244
                        (AC-FT)    2018.      2210.       2210.       2210.

                      CUMULATIVE AREA =    7.90 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
187 KK    *      S-B2  *
          *            *
          **************
                         Runoff from Sub-basin B2

            SUBBASIN RUNOFF DATA

189 BA          SUBBASIN CHARACTERISTICS
```

```
                TAREA        1.36  SUBBASIN AREA

            PRECIPITATION DATA

92 PB           STORM       12.76  BASIN TOTAL PRECIPITATION

92 PI         INCREMENTAL PRECIPITATION PATTERN
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                .00       .00       .00       .00       .00       .00       .00       .00       .00       .00

190 LG        GREEN AND AMPT LOSS RATE
                STRTL        .31  STARTING LOSS
                  DTH        .26  MOISTURE DEFICIT
                 PSIF       4.35  WETTING FRONT SUCTION
                XKSAT        .46  HYDRAULIC CONDUCTIVITY
                RTIMP      15.00  PERCENT IMPERVIOUS AREA

191 UC        CLARK UNITGRAPH
                   TC       1.87  TIME OF CONCENTRATION
                    R       1.64  STORAGE COEFFICIENT

            SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

                                          ***

                                   UNIT HYDROGRAPH PARAMETERS
                             CLARK   TC=  1.87 HR,       R=  1.64 HR
                            SNYDER   TP=  1.74 HR,      CP=   .62

                                      UNIT HYDROGRAPH
                                 291 END-OF-PERIOD ORDINATES
          1.        3.        7.       12.       17.       22.       28.       35.       42.       49.
         56.       64.       72.       80.       89.       97.      106.      115.      124.      133.
        142.      152.      161.      171.      180.      190.      200.      210.      220.      229.
        238.      247.      255.      263.      270.      277.      283.      289.      295.      300.
        305.      309.      313.      316.      319.      321.      323.      325.      326.      327.
        327.      326.      325.      323.      320.      317.      311.      305.      299.      293.
        287.      281.      276.      270.      265.      259.      254.      249.      244.      239.
        234.      230.      225.      220.      216.      212.      207.      203.      199.      195.
        191.      187.      184.      180.      176.      173.      169.      166.      163.      159.
        156.      153.      150.      147.      144.      141.      138.      135.      133.      130.
        127.      125.      122.      120.      117.      115.      113.      111.      108.      106.
        104.      102.      100.       98.       96.       94.       92.       90.       88.       87.
         85.       83.       81.       80.       78.       77.       75.       74.       72.       71.
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 69. | 68. | 67. | 65. | 64. | 63. | 61. | 60. | 59. | 58. |
| 57. | 55. | 54. | 53. | 52. | 51. | 50. | 49. | 48. | 47. |
| 46. | 45. | 44. | 43. | 43. | 42. | 41. | 40. | 39. | 38. |
| 38. | 37. | 36. | 35. | 35. | 34. | 33. | 33. | 32. | 31. |
| 31. | 30. | 30. | 29. | 28. | 28. | 27. | 27. | 26. | 26. |
| 25. | 25. | 24. | 24. | 23. | 23. | 22. | 22. | 21. | 21. |
| 20. | 20. | 20. | 19. | 19. | 18. | 18. | 18. | 17. | 17. |
| 17. | 16. | 16. | 16. | 15. | 15. | 15. | 14. | 14. | 14. |
| 14. | 13. | 13. | 13. | 13. | 12. | 12. | 12. | 12. | 11. |
| 11. | 11. | 11. | 10. | 10. | 10. | 10. | 10. | 9. | 9. |
| 9. | 9. | 9. | 9. | 8. | 8. | 8. | 8. | 8. | 8. |
| 7. | 7. | 7. | 7. | 7. | 7. | 7. | 6. | 6. | 6. |
| 6. | 6. | 6. | 6. | 6. | 5. | 5. | 5. | 5. | 5. |
| 5. | 5. | 5. | 5. | 5. | 4. | 4. | 4. | 4. | 4. |
| 4. | 4. | 4. | 4. | 4. | 4. | 4. | 3. | 3. | 3. |
| 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. | 3. |
| 3. | | | | | | | | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-B2
FOR PLAN 1, RATIO = .50

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.10, TOTAL EXCESS = 9.66

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 2907. | 4.87 | (CFS) | 1329. | 507. | 507. | 507. |
| | | (INCHES) | 9.085 | 9.612 | 9.612 | 9.612 |
| | | (AC-FT) | 659. | 697. | 697. | 697. |

CUMULATIVE AREA = 1.36 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION S-B2
FOR PLAN 1, RATIO = .50

| PEAK FLOW (CFS) | TIME (HR) | | MAXIMUM AVERAGE FLOW 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 1454. | 4.87 | (CFS) | 664. | 254. | 254. | 254. |
| | | (INCHES) | 4.542 | 4.806 | 4.806 | 4.806 |
| | | (AC-FT) | 329. | 349. | 349. | 349. |

CUMULATIVE AREA = 1.36 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
192 KK    **************
          *            *
          *     C-C7   *
          *            *
          **************
```

Combine C-C6 and S-B2

```
194 HC          HYDROGRAPH COMBINATION
                     ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION     C-C7
                        FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
  11026.      4.73       (CFS)     4735.       1861.       1861.       1861.
                       (INCHES)    4.753       5.180       5.180       5.180
                        (AC-FT)    2348.       2558.       2558.       2558.

                       CUMULATIVE AREA =    9.26 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
195 KK    *     S-C1   *
          *            *
          **************
                         Runoff from Sub-basin C1

             SUBBASIN RUNOFF DATA

197 BA          SUBBASIN CHARACTERISTICS
                     TAREA        2.54  SUBBASIN AREA

                PRECIPITATION DATA

 92 PB               STORM       12.76  BASIN TOTAL PRECIPITATION

 92 PI            INCREMENTAL PRECIPITATION PATTERN
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .06       .06       .06       .06       .06       .06       .06       .04       .02       .02
                     .02       .02       .02       .02       .02       .01       .01       .01       .01       .01
                     .01       .01       .01       .01       .01       .01       .01       .01       .01       .01
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                     .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
```

```
198 LG          GREEN AND AMPT LOSS RATE
                     STRTL          .31  STARTING LOSS
                       DTH          .26  MOISTURE DEFICIT
                      PSIF         4.35  WETTING FRONT SUCTION
                     XKSAT          .46  HYDRAULIC CONDUCTIVITY
                     RTIMP        15.00  PERCENT IMPERVIOUS AREA

199 UC          CLARK UNITGRAPH
                        TC         1.07  TIME OF CONCENTRATION
                         R          .63  STORAGE COEFFICIENT

200 UA          ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                      .0       5.0      16.0      30.0      65.0      77.0      84.0      90.0      94.0      97.0
                   100.0

                                                   ***

                                                UNIT HYDROGRAPH PARAMETERS
                                         CLARK   TC=  1.07 HR,       R=   .63 HR
                                        SNYDER   TP=   .55 HR,      CP=   .47

                                                 UNIT HYDROGRAPH
                                            114 END-OF-PERIOD ORDINATES
              20.      59.      95.     149.     224.     299.     378.     465.     552.     665.
             856.    1090.    1297.    1402.    1424.    1446.    1447.    1429.    1410.    1390.
            1367.    1343.    1317.    1284.    1250.    1215.    1179.    1141.    1106.    1073.
            1041.    1011.     971.     922.     874.     829.     786.     745.     707.     670.
             635.     602.     571.     541.     513.     487.     461.     437.     415.     393.
             373.     354.     335.     318.     301.     286.     271.     257.     244.     231.
             219.     208.     197.     187.     177.     168.     159.     151.     143.     136.
             129.     122.     116.     110.     104.      98.      93.      89.      84.      80.
              75.      72.      68.      64.      61.      58.      55.      52.      49.      47.
              44.      42.      40.      38.      36.      34.      32.      31.      29.      27.
              26.      25.      23.      22.      21.      20.      19.      18.      17.      16.
              15.      14.      14.      13.

   ***          ***          ***          ***          ***

                     HYDROGRAPH AT STATION     S-C1
                       FOR PLAN 1, RATIO =  .50

  TOTAL RAINFALL =   12.76, TOTAL LOSS =    3.10, TOTAL EXCESS =    9.66

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
  10683.      3.87        (CFS)     2616.       947.        947.        947.
                        (INCHES)    9.575      9.613       9.613       9.613
                         (AC-FT)    1297.      1302.       1302.       1302.

                      CUMULATIVE AREA =    2.54 SQ MI

   ***          ***          ***          ***          ***

                     HYDROGRAPH AT STATION     S-C1
                       FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
   5341.      3.87        (CFS)     1308.       474.        474.        474.
```

```
                    (INCHES)     4.787       4.807       4.807       4.807
                     (AC-FT)      649.        651.        651.        651.

                    CUMULATIVE AREA =    2.54 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
202 KK    *      C-C8  *
          *            *
          **************
                         Combine C-C7 and S-C1

204 HC          HYDROGRAPH COMBINATION
                     ICOMP           2  NUMBER OF HYDROGRAPHS TO COMBINE

                                                          ***

    ***            ***            ***            ***            ***

                      HYDROGRAPH AT STATION     C-C8
                        FOR PLAN 1, RATIO =  .50

PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
  (CFS)       (HR)                 6-HR       24-HR       72-HR     16.63-HR
  13936.      4.53       (CFS)     6008.       2335.       2335.       2335.
                       (INCHES)    4.734       5.100       5.100       5.100
                        (AC-FT)    2979.       3210.       3210.       3210.

                      CUMULATIVE AREA =   11.80 SQ MI
```

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
205 KK    *      S-D1  *
          *            *
          **************
                         Runoff from Sub-basin D1

            SUBBASIN RUNOFF DATA

207 BA          SUBBASIN CHARACTERISTICS
                     TAREA         1.15  SUBBASIN AREA

                PRECIPITATION DATA

 92 PB               STORM        12.76  BASIN TOTAL PRECIPITATION

 92 PI            INCREMENTAL PRECIPITATION PATTERN
                      .00        .00        .00        .00        .00        .00        .00        .00        .00        .00
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .06 | .06 | .06 | .06 | .06 | .06 | .06 | .04 | .02 | .02 |
| .02 | .02 | .02 | .02 | .02 | .01 | .01 | .01 | .01 | .01 |
| .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |

208 LG GREEN AND AMPT LOSS RATE

| | | |
|---|---|---|
| STRTL | .30 | STARTING LOSS |
| DTH | .27 | MOISTURE DEFICIT |
| PSIF | 3.64 | WETTING FRONT SUCTION |
| XKSAT | .67 | HYDRAULIC CONDUCTIVITY |
| RTIMP | 17.00 | PERCENT IMPERVIOUS AREA |

209 UC CLARK UNITGRAPH

| | | |
|---|---|---|
| TC | .90 | TIME OF CONCENTRATION |
| R | .65 | STORAGE COEFFICIENT |

SYNTHETIC ACCUMULATED-AREA VS. TIME CURVE WILL BE USED

***

UNIT HYDROGRAPH PARAMETERS

CLARK TC= .90 HR, R= .65 HR

SNYDER TP= .80 HR, CP= .67

UNIT HYDROGRAPH

118 END-OF-PERIOD ORDINATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6. | 21. | 44. | 71. | 101. | 133. | 168. | 204. | 241. | 280. |
| 319. | 359. | 399. | 440. | 478. | 513. | 543. | 569. | 591. | 609. |
| 623. | 633. | 639. | 641. | 638. | 629. | 614. | 589. | 559. | 531. |
| 505. | 479. | 455. | 433. | 411. | 390. | 371. | 352. | 335. | 318. |
| 302. | 287. | 272. | 259. | 246. | 234. | 222. | 211. | 200. | 190. |
| 181. | 172. | 163. | 155. | 147. | 140. | 133. | 126. | 120. | 114. |
| 108. | 103. | 98. | 93. | 88. | 84. | 79. | 75. | 72. | 68. |
| 65. | 61. | 58. | 55. | 53. | 50. | 47. | 45. | 43. | 41. |
| 39. | 37. | 35. | 33. | 31. | 30. | 28. | 27. | 26. | 24. |
| 23. | 22. | 21. | 20. | 19. | 18. | 17. | 16. | 15. | 15. |
| 14. | 13. | 12. | 12. | 11. | 11. | 10. | 10. | 9. | 9. |
| 8. | 8. | 7. | 7. | 7. | 6. | 6. | 6. | | |

*** *** *** *** ***

HYDROGRAPH AT STATION S-D1

FOR PLAN 1, RATIO = .50

TOTAL RAINFALL = 12.76, TOTAL LOSS = 3.46, TOTAL EXCESS = 9.30

PEAK FLOW TIME MAXIMUM AVERAGE FLOW

| (CFS) | (HR) | | 6-HR | 24-HR | 72-HR | 16.63-HR |
|---|---|---|---|---|---|---|
| 4833. | 3.97 | (CFS) | 1139. | 413. | 413. | 413. |
| | | (INCHES) | 9.207 | 9.251 | 9.251 | 9.251 |
| | | (AC-FT) | 565. | 567. | 567. | 567. |

CUMULATIVE AREA = 1.15 SQ MI

*** *** *** *** ***

HYDROGRAPH AT STATION S-D1
FOR PLAN 1, RATIO = .50

| PEAK FLOW | TIME | | MAXIMUM AVERAGE FLOW | | | |
|---|---|---|---|---|---|---|
| (CFS) | (HR) | | 6-HR | 24-HR | 72-HR | 16.63-HR |
| 2417. | 3.97 | (CFS) | 569. | 206. | 206. | 206. |
| | | (INCHES) | 4.603 | 4.625 | 4.625 | 4.625 |
| | | (AC-FT) | 282. | 284. | 284. | 284. |

CUMULATIVE AREA = 1.15 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
210 KK    *      C-C9  *
          *            *
          **************
```

Combine C-C8 and S-D1

212 HC HYDROGRAPH COMBINATION
ICOMP 2 NUMBER OF HYDROGRAPHS TO COMBINE

***

*** *** *** *** ***

HYDROGRAPH AT STATION C-C9
FOR PLAN 1, RATIO = .50

| PEAK FLOW | TIME | | MAXIMUM AVERAGE FLOW | | | |
|---|---|---|---|---|---|---|
| (CFS) | (HR) | | 6-HR | 24-HR | 72-HR | 16.63-HR |
| 15540. | 4.43 | (CFS) | 6568. | 2541. | 2541. | 2541. |
| | | (INCHES) | 4.715 | 5.057 | 5.057 | 5.057 |
| | | (AC-FT) | 3257. | 3493. | 3493. | 3493. |

CUMULATIVE AREA = 12.95 SQ MI

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

```
          **************
          *            *
```

```
213 KK      *       RES  *
            *            *
            **************
                          Spook Hill Reservoir Routing
                          See DMJM+HARRIS Technical Report No. 1 for supporting details
                          behind rating curves.

                          NGVD 29 elevations used in the computations.

                          Sediment Storage Volume Below Principle Spillway = 271 Ac-Ft (Elev=1577.5')

                HYDROGRAPH ROUTING DATA

221 RS            STORAGE ROUTING
                       NSTPS          1  NUMBER OF SUBREACHES
                        ITYP       STOR  TYPE OF INITIAL CONDITION
                      RSVRIC        .00  INITIAL CONDITION
                           X        .00 WORKING R AND D COEFFICIENT

222 SV              STORAGE         .0     287.0     346.0     474.9     693.0    1120.0    1631.0    1919.0    2231.0    2927.0
                                 3722.0    4158.0

224 SQ            DISCHARGE         0.        0.      250.      500.      750.      990.     2860.     4750.     7000.    12750.
                                19240.    23050.

226 SE            ELEVATION     1575.10   1577.50   1578.00   1578.80   1580.00   1582.00   1584.00   1585.00   1586.00   1588.00
                                1590.00   1591.00

                                                                   ***

     ***            ***            ***            ***            ***

                        HYDROGRAPH AT STATION      RES
                          FOR PLAN 1, RATIO =  .50

 PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
   (CFS)       (HR)                  6-HR       24-HR       72-HR     16.63-HR
   5920.       6.17        (CFS)     3918.      1876.       1876.       1876.
                         (INCHES)    2.813      3.734       3.734       3.734
                          (AC-FT)    1943.      2579.       2579.       2579.

PEAK STORAGE   TIME                          MAXIMUM AVERAGE STORAGE
  (AC-FT)      (HR)                  6-HR       24-HR       72-HR     16.63-HR
   2081.       6.17                 1770.      1093.       1093.       1093.

 PEAK STAGE    TIME                          MAXIMUM AVERAGE STAGE
   (FEET)      (HR)                  6-HR       24-HR       72-HR     16.63-HR
  1585.52      6.17               1584.45    1581.30     1581.30     1581.30

                        CUMULATIVE AREA =   12.95 SQ MI
```

PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
TIME TO PEAK IN HOURS

RATIOS APPLIED TO FLOWS

| OPERATION | STATION | AREA | PLAN | | RATIO 1 .50 |
|---|---|---|---|---|---|
| HYDROGRAPH AT | S-IN | .00 | 1 | FLOW | 157. |
| | | | | TIME | .80 |
| HYDROGRAPH AT | S-F | .15 | 1 | FLOW | 265. |
| | | | | TIME | 4.13 |
| 2 COMBINED AT | C-C1 | .15 | 1 | FLOW | 422. |
| | | | | TIME | 4.13 |
| DIVERSION TO | DV-F | .15 | 1 | FLOW | 0. |
| | | | | TIME | .00 |
| HYDROGRAPH AT | DIVF | .15 | 1 | FLOW | 422. |
| | | | | TIME | 4.13 |
| ROUTED TO | R-F | .15 | 1 | FLOW | 417. |
| | | | | TIME | 4.37 |
| | | | ** PEAK STAGES IN FEET ** | | |
| | | | 1 | STAGE | 5.40 |
| | | | | TIME | 4.37 |
| HYDROGRAPH AT | S-G | .52 | 1 | FLOW | 1290. |
| | | | | TIME | 4.03 |
| 2 COMBINED AT | C-C2 | .67 | 1 | FLOW | 1650. |
| | | | | TIME | 4.07 |
| DIVERSION TO | DV-G | .67 | 1 | FLOW | 346. |
| | | | | TIME | 4.07 |
| HYDROGRAPH AT | DIVG | .67 | 1 | FLOW | 1304. |
| | | | | TIME | 3.73 |
| ROUTED TO | R-G-1 | .67 | 1 | FLOW | 1304. |
| | | | | TIME | 4.20 |
| | | | ** PEAK STAGES IN FEET ** | | |
| | | | 1 | STAGE | 8.22 |
| | | | | TIME | 4.23 |
| ROUTED TO | R-G-2 | .67 | 1 | FLOW | 1304. |
| | | | | TIME | 4.20 |
| | | | ** PEAK STAGES IN FEET ** | | |
| | | | 1 | STAGE | 4.25 |
| | | | | TIME | 4.27 |
| HYDROGRAPH AT | S-H | .86 | 1 | FLOW | 813. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | TIME | 5.03 |
| 2 COMBINED AT | C-C3 | 1.53 | 1 | FLOW | 2030. |
| | | | | TIME | 4.67 |
| DIVERSION TO | DV-H | 1.53 | 1 | FLOW | 0. |
| | | | | TIME | .00 |
| HYDROGRAPH AT | DIVH | 1.53 | 1 | FLOW | 2030. |
| | | | | TIME | 4.67 |
| ROUTED TO | R-H | 1.53 | 1 | FLOW | 2028. |
| | | | | TIME | 4.70 |
| | | | ** PEAK STAGES IN FEET ** | | |
| | | | 1 | STAGE | 5.79 |
| | | | | TIME | 4.70 |
| HYDROGRAPH AT | S-I | 1.32 | 1 | FLOW | 1353. |
| | | | | TIME | 5.00 |
| 2 COMBINED AT | C-C4 | 2.85 | 1 | FLOW | 3311. |
| | | | | TIME | 4.73 |
| DIVERSION TO | DV-I | 2.85 | 1 | FLOW | 439. |
| | | | | TIME | 4.73 |
| HYDROGRAPH AT | DIVI | 2.85 | 1 | FLOW | 2872. |
| | | | | TIME | 4.33 |
| HYDROGRAPH AT | S-A1 | .96 | 1 | FLOW | 1598. |
| | | | | TIME | 4.27 |
| 2 COMBINED AT | C-C5 | 3.81 | 1 | FLOW | 4457. |
| | | | | TIME | 4.33 |
| HYDROGRAPH AT | S-B1 | 4.09 | 1 | FLOW | 5522. |
| | | | | TIME | 4.83 |
| 2 COMBINED AT | C-C6 | 7.90 | 1 | FLOW | 9597. |
| | | | | TIME | 4.73 |
| HYDROGRAPH AT | S-B2 | 1.36 | 1 | FLOW | 1454. |
| | | | | TIME | 4.87 |
| 2 COMBINED AT | C-C7 | 9.26 | 1 | FLOW | 11026. |
| | | | | TIME | 4.73 |
| HYDROGRAPH AT | S-C1 | 2.54 | 1 | FLOW | 5341. |
| | | | | TIME | 3.87 |
| 2 COMBINED AT | C-C8 | 11.80 | 1 | FLOW | 13936. |
| | | | | TIME | 4.53 |
| HYDROGRAPH AT | S-D1 | 1.15 | 1 | FLOW | 2417. |
| | | | | TIME | 3.97 |
| 2 COMBINED AT | C-C9 | 12.95 | 1 | FLOW | 15540. |
| | | | | TIME | 4.43 |

```
ROUTED TO          RES     12.95     1   FLOW        5920.
                                         TIME         6.17

                                     ** PEAK STAGES IN FEET **
                                     1   STAGE     1585.52
                                         TIME         6.17


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

# APPENDIX F

# FEIS Correspondence

# (FCDMC Letters)

FLOOD CONTROL DISTRICT of MARICOPA COUNTY 1959

FLOOD CONTROL DISTRICT

February 23, 1999

Mr. Terry Bourland
Project Manager
ADOT Valley Project Management
Arizona Department of Transportation
205 South 17th Avenue
Room 295, MD 614E
Phoenix, Arizona 85007-3212

**RE: Spook Hill Flood Retarding Structure**
**Red Mountain Freeway; SR 87 to US 60 EIS**

Dear Mr. Bourland:

The purpose of this letter is to respond to your letter dated October 22, 1998, regarding the impacts of the "two-dam" concept as defined in the *Red Mountain Freeway, Lindsay Road to Baseline Road, Design Concept Report* (ADOT, 1988). Subject to approval by the Board of Directors, the District does not object to the construction of the Red Mountain Freeway as defined in the DCR if the following conditions are met:

1. ADOT will provide funding for costs of all administration, project management, necessary permits, investigations, studies, engineering, design, right-of-way, utility relocations and construction of modifications to the existing dam structure.

2. Flood detention volume will remain as currently designed. Any additional, necessary right-of-way to maintain the impoundment area will be provided by ADOT.

3. The District would assist ADOT with obtaining the applicable land rights for lands currently controlled by the District for the freeway structures and interchange ramps. The District will retain remaining land rights for the flood retarding structure and impoundment area. ADOT will transfer applicable land rights obtained to maintain the impoundment area to the District. A joint-use agreement will be prepared to permit ADOT to construct and maintain landscaping and fencing applicable to the freeway.

4. ADOT must provide operation and maintenance access to each end of each segment of the dam as bisected by roadway crossings at McDowell Road, McKellips Road and Brown Road. The District will be responsible for operation and maintenance of

AG32

AG32 – The conditions within the letter have been included as mitigation in the FEIS.

Page 2
February 23, 1999
Spook Hill Flood Retarding Structure, Red Mountain Freeway; SR 87 to US 60 EIS

the modified dam and impoundment area. ADOT will be responsible for maintenance of the freeway and associated interchanges.

5. ADOT will be responsible for the costs of preparing and/or updating existing dam-break analysis, overflow spillway delineation analysis and spillway inundation studies as prepared or caused to be prepared by the District. Impact of the freeway construction as defined in these studies will have to be evaluated and mitigated.

6. ADOT will be responsible for the costs of the District to prepare or cause to be prepared all designs for the modification of the dam. Dam modifications will have to meet all current technical standards to include approval by the Arizona Department of Water Resources and any other applicable agency.

7. ADOT will be responsible for the costs of the District to review and re-delineate any floodplains affected by the freeway.

8. ADOT will be responsible for any other costs associated with required studies and/or investigations pertaining to modifications to the dam structure or the impoundment area.

9. All existing intergovernmental agreements associated with existing features of the Spook Hill FRS, the Signal Butte floodway and related structures must be complied with and/or negative impacts mitigated.

10. ADOT will obtain or cause to be obtained or updated any required 404 Permits and/or Environmental Assessments.

I hope this letter will assist you with furthering the Red Mountain Freeway as it impacts the Spook Hill FRS and related facilities. If you have any questions, please do not hesitate to contact me or Tim Phillips at 506-4718.

Sincerely,

Michael S. Ellegood, P.E.
Chief Engineer and General Manager

AG32
Con't

**FLOOD CONTROL DISTRICT**
**of**
**Maricopa County**

2801 West Durango Street • Phoenix, Arizona 85009-6399
Telephone (602) 506-1501
Fax (602) 506-4601
TT (602) 506-5897

VALLEY PROJECT MANAGEMENT
BOARD OF DIRECTORS
Betsey Bayless
Jan Brewer
Fulton Brock
Don Stapley
Mary Rose Garrido Wilcox

MAR 24 1998

Mr. Richard M. Duarte, Manager
Environmental Planning Section
Arizona Department of Transportation
205 South 17th Avenue, Mail Drop 619E
Phoenix, Arizona 85007

Subject: Red Mountain Freeway (Loop 202), SR87 to US60, Draft Environmental Impact Statement

Dear Mr. Duarte:

The Flood Control District (District) has reviewed the subject report dated December 30, 1997, and has the following comments:

*General Comments:*

1- The three proposed alternative alignments for Loop 202 impact two structures owned and operated by the District, the Spookhill Flood Retarding Structure (FRS) and the Signal Butte Floodway. Both structures were designed and constructed by the Natural Resources Conservation Service. Based on Figure S-4, the 1988-1989 and the Red Mountain Bypass alternatives cross over the Emergency Spillway for the Spookhill FRS. The Spookhill FRS is subject to rules and regulations relevant to the Safety of Dams as set forth by the State Department of the Water Resources (ADWR). Therefore, the report as a whole must address impacts on the function and operation of the FRS beyond the 100-year level. This includes concerns such as operation of the emergency spillway, conveyance of the flows during the Probable Maximum Flood, emergency repairs and access during emergency operations.

2- All three alternatives will require 404 Permits as they cross the Spookhill FRS and the Signal Butte Floodway. Furthermore, any changes to the structure or the reservoir area of Spookhill may require an update of the Environmental Assessment report for Spookhill FRS.

3- The following comment will apply to all of the following sections; S-21, S-25, and 5-28 (Land Ownership on Spookhill FRS): from the District's standpoint, as long as the BLM continues to allow the District to use the land for flood control purposes as originally developed, then perhaps multiple or joint uses could be acceptable. The District would strongly resist any attempts to delete from the District's authority any property rights which would make the continued construction, operation or maintenance of the district levees, stormwater structures or ponding areas impossible. Any future actions to modify or change the character of the existing land rights in this area must be subject to existing rights and easements in order to minimize any impacts to flood control structures. Finally, if the past FCD rights are not grandfathered in, or additional uses being subject to prior rights, the health and safety of downstream citizens would be jeopardized. The district must retain the ability to access the flood control facilities to maintain the structural integrity and operation of the facilities.

*Specific Comments:*

1- Pg. S-5, Fig. S-2, NOTES: include the Spookhill FRS and Signal Butte Floodway.

2- Pg. S-7, third paragraph, line 8: ...would cross the CAP and (add) *Spookhill FRS*...

AG33 **AG33** - Both the 1988-1989 Alignment Alternative (Eastern Section) and the Red Mountain District Park Bypass Alignment Alternative would be designed to span the Signal Butte Floodway and not affect the function and operation of the facility, (including operation of the emergency spillway, emergency repairs and access during emergency operations) in accordance with *Rules and Regulations Pertaining to Dam Safety Procedures* (**ADWR, 1998**). Both alternatives will span the Emergency Spillway for the Spookhill Flood Retarding Structure (FRS), thus, avoiding impacts as well.

AG34 **AG34** - A Section 404 individual permit will be obtained upon the Record of Decision for the proposed action (see Section 4.7, *Jurisdictional Waters Of The United States*, and **Appendix B**, *Sections 401 and 404*).

AG35 **AG35** - The proposed action will not preclude the FCDMC from retaining the ability to access the flood control facilities to maintain the structural integrity and operation of the facilities, as identified in Section 4.6.5, *Mitigation*. Any transfer of property rights will be conducted in a manner that would not jeopardize the health and safety of downstream citizens and would be done with full involvement with the FCDMC. See **Appendix A**, *Agency Letters, Responses and Scoping Comments*, which depicts correspondence between the City of Mesa and BLM regarding this matter.

AG36 **AG36** - Text has been modified.

AG37 **AG37** - Text has been modified.

3- Pg. S-7, third paragraph, line 11: ...follow the Hawes Road alignment (add) *crossing Spookhill FRS.*

4- Pg. S-9, Fig. S-4: show alignments for Spookhill FRS and Signal Butte Floodway.

5- Pg. S-10, first paragraph, line 4: ...the alignment would (add) *cross CAP and the Spookhill FRS* and turn southeast...

6- Pg. S-10, first paragraph, line 8: ...turn southeasterly (add) *crossing Signal Butte Floodway...*

7- Pg. S-14, Fig. S-7: show Spookhill and Signal Butte Alignments.

8- Pg. S-25, paragraph 1: per ADWR criteria, both conveyance capacity and the storage capacity within the FRS ponding area must be maintained for all flows up to and including the Probable Maximum Flood (PMF). All alternatives must address flows above 100-year frequency.

9- Pg. 2-15: see comments #2, 3, 5 and 6.

10- Pg. 2-19, Fig. 2-6: show location of Spookhill FRS on all profiles.

11- Pg. 2-21, paragraph 1, line 1: ...but below the maximum flood elevation (~~500-year flood~~) (Probable Maximum Flood).

12- Pg. 2-21, paragraph 1, line 2: ...elevated to cross the (add) *Spookhill FRS and...*

13- Pg. 2-21, paragraph 2, line 9: ...cross the roadway and the CAP canal (add) *and the Spookhill FRS...*

14- Pg. 2-21, paragraph 3, line 6:...be elevated as required for cross drainage (add) *and the operations of the Spookhill emergency spillway...*

15- Pg. 2-22, Table 2-1: add a note on the impacts of the Half Diamond Interchange for Power Road on the Emergency Spillway operations.

16- Pg. 2-26, paragraph 1, line 5: add NRCS to the coordination list.

17- Pg. 2-26, paragraph 1, line 7: ...along the Spookhill FRS (add) *and the Signal Butte Floodway.*

18- Figures 3-4, 3-6, 3-8, 3-24 and 3-25: include and label alignment for the Signal Butte Floodway.

19- Pg. 3-7, last paragraph: discuss effects on the Signal Butte Floodway.

20- Pg. 3-46, Section 3.6.1: newest maps and Zone definitions by FEMA were published September 1995.

21- Pg. 3-46, second paragraph: see General Comments and specific comments 8 and 11 above.

22- Pg. 3-46, paragraph 4, line 1: The (add) *principal* spillway for Spookhill FRS ...

23- Pg. 3-50, Section 3.6.3: During July 17-18, 1984, a major storm in the area caused flooding and damage to residences and the CAP (under construction at that time). This flooding effected the southern reach of the proposed alignments.

Additionally, the 1993 floods in Salt River eroded part of the Tri-City Landfill in the vicinity of the project.

24- Pg. 3-51, Section 3.7: include impacts on the Signal Butte Floodway.

25- Pg. 4-54, Section 4.5.3: see General Comments, operation of the FRS must include all flows up to and including the PMF.

26- Pg. 4-55, first paragraph: address issues concerning the operation of the FRS, including total storage, conveyance, access, function, emergency operations, emergency spillway, etc.

27- Pg. 4-55, Sections 4.5.3.2 and 4.5.3.3: lateral and cross drainage must address the Safety of the Dam criteria, including the operation of the Dam at PMF level.

28- Pg. 4-57, Section 4.6.1: see comments 25-27.

29- Pg. 4-63, Section 4.6.1.7: based on the above comments, the proposed alignments will have significant impacts on the operation of the FRS unless mitigation efforts are undertaken.

AG38

AG39

AG40

AG41

AG42

AG43

AG44

AG45

AG46

AG47

AG48

AG49

AG50

AG51

AG52

AG53

AG54

AG38 - Text has been modified.

AG39 - Spookhill and Signal Butte alignments have been added to the figure.

AG40 - Text has been modified.

AG41 - Figure has been modified.

AG42 - Text has been modified.

AG43 - Text has been modified.

AG44 - Figure has been modified.

AG45 - Text has been modified.

AG46 - The suggested change will not be made in Table 2-1. Table 2-1 is intended to describe the traffic interchange configuration at each of the locations; a footnote will be added to reference Section 4.6, *Floodplains*. Impacts resulting from any of the proposed traffic interchanges are described throughout Chapter 4, *Environmental Consequences*.

AG47 - Text has been modified.

AG48 - Figures have been modified.

AG49 - Text has been modified.

AG50 - The text referenced and **Figures 3-19, 20,** and **21** are correct as shown.

AG51 - Text has been modified.

AG52 - The text referenced is correct as shown.

AG53 - Text has been modified.

AG54 - Text has been revised to indicate that both alternatives will span the Emergency Spillway for the Spookhill Flood Retarding Structure (FRS), thus, avoiding impacts. Chapter 3, *Affected Environment*, discusses affected environment. The impacts on the Signal Butte Floodway are presented in Section 4.6, *Floodplains*.

30- Pg. 4-64, Section 4.6.3: see comment 29 above.

31- Pg. 4-65: see comments 29 above. This section should be revised to include mitigation for all flows up to the PMF level.

32- Appendix A, Pg. A-2: all correspondence to the Flood Control District of Maricopa County should be addressed to Mr. Michael S. Ellegood, P.E., Chief Engineer and General Manager.

Please feel free to contact Amir Motamedi at 506-4871 if you have any questions.

Sincerely,

Michael S. Ellegood, P.E.
Chief Engineer and General Manager

Copy to: Jack Allen, Entranco

AG54 Con't

AG55 AG55 - Text has been modified.