1997

Computerized flood prediction modeling of the Squaw Creek basin using the HEC1 model

Karla Kay Heeren Tebben
Iowa State University

Recommended Citation

Tebben, Karla Kay Heeren, "Computerized flood prediction modeling of the Squaw Creek basin using the HEC1 model" (1997). *Retrospective Theses and Dissertations*. 16990.
https://lib.dr.iastate.edu/rtd/16990

Computerized flood prediction modeling of the Squaw Creek basin using the HEC1 model

by

Karla Kay Heeren Tebben

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Civil Engineering (Environmental Engineering)
Major Professor: T. Al Austin

Iowa State University
Ames, Iowa
1997

Graduate College
Iowa State University

This is to certify that the Master's thesis of

Karla Kay Heeren Tebben

has met the thesis requirements of Iowa State University

DEDICATION

This thesis is dedicated to my husband, Don, and my children, Cheryl and Robert, whose patience, understanding and support enable me to reach the goals I set for myself.

TABLE OF CONTENTS

INTRODUCTION

The Squaw Creek drainage basin has been the location of numerous flooding events throughout its history. Located in northwestern Story, northeastern Boone and southwestern Hamilton counties in Iowa, the basin's 227 square miles consist mostly of agricultural land and small rural residential subdivisions. The only large urban-type area of the basin, the city of Ames, is located at the southern section of the basin where Squaw Creek joins the Skunk River. The most recent and most damaging of the recorded flooding events on the Squaw Creek basin occurred in July of 1993. Notable recorded flooding events with flows greater than 4000 cubic feet per second (cfs) are listed in Table 1 (Glanville, 1987 and U.S. Department of the Interior, 1985, 1991, 1994).

Table 1. Notable recorded floods (greater than 4000 cfs) on the Squaw Creek basin

Date	Gage Height[a] (feet)	Discharge (cfs)
June 4, 1918	14.5	6900
July 17, 1922	10.7	4130
March 1, 1965	10.70	4200
June 27, 1975	14.00	11300
March 19, 1979	11.81	5300
June 13, 1984	12.97	7180
June 17, 1984	12.77	6820
June 17, 1990	15.50	12500
July 9, 1993	18.50	24300
July 13, 1993	13.92	8660
July 17, 1993	15.03	11090

[a] Present gage was installed in 1965. Prior to 1925, a non-recording gage was located 0.6 miles upstream from the present gage at a different datum. No official gage was maintained from May 1927 to February 1965.

The flood of 1993 was a challenge for most residents of midwestern United States. A persistent wet-weather pattern in June and July followed a period of greater than average precipitation in the upper Midwest region of the United States. In many midwestern areas rainfall totals from January to July of 1993 were one and one-half to two times the average precipitation for the same 7-month time period (Parrett, 1993). With saturated soils on most stream and river basins, almost all rainfall falling by late May to early June became direct runoff. This was the scenario in Ames during late June and early July when a stationary front parked over the Midwest depositing 2 to 5 inches of rain with each rainfall event. The most damaging storm for Ames tracked through the Squaw Creek basin from northwest to southeast dropping rain on top of flood waters routing down Squaw Creek. As a result, Ames residents dealt with unprecedented quantities of flood water as well as economic loss. The economic loss suffered by Ames residents and businesses due to the 1993 flood totaled well over $10 million (Snyder & Associates, 1996).

The National Weather Service (NWS) is the federal agency responsible for issuing river forecasts and flood warnings. Thirteen NWS river forecasting centers prepare river flood forecasts for the nation using calibrated and verified models developed for forecast service points located on major rivers (U.S. Geological Survey, 1996). Unfortunately, Squaw Creek is not considered to be a major river and has not been selected as a forecast service point by the NWS. Therefore, a local flood prediction model is necessary to provide local officials a means of predicting maximum flooding discharge and time to peak at the damage centers in Ames.

Squaw Creek residents are not the only group nationally who have discovered the need for a local flood warning system. Many municipalities and state organizations have developed their own local flood prediction system. A term often used for a local flood prediction system is ALERT which stands for Automated Local Evaluation in Real Time (Rooke, 1996a). ALERT users in two regions of the country have come together to form user groups, the ALERT User's Group (Western United States) and the Southwestern Association of ALERT Systems (Southwestern United States). Another group is currently being formed in the Eastern United States. These groups help member communities find information on vendors of hardware and software, software packages, hydrologic data, and system setup and maintenance. The first two user groups have also organized the National Hydrologic Warning Council whose mission it is "to provide national coordination and to become an effective voice for the flood warning community in Congress" (Rooke, 1996a). The very presence of these groups indicates the widespread use of local flood warning systems. It should be noted that no user group currently exists for the midwestern ALERT system users.

ALERT systems do vary considerably in the degree of complexity of the systems being used. One community may need not much more than an automated stream gage as a warning of the stream levels upstream from the community. Other communities have very complex systems of stream and precipitation gages linked electronically to hydrologic models of the basins (DeGroot, 1980, pp. 201-204), (King, 1980, pp. 205-212), (Luker, 1993, pp.303-311), (Fleming, 1986, pp. 329-366), (Rooke, 1996b). Still other ALERT systems are being developed on a more regional basis. A collaborative effort of Sentar, Inc., NASA Marshall Space Flight Center, the Alabama Emergency Management Agency, and the U.S. Army Space and Strategic Defense Command is currently underway to develop a means to use remote sensing data for flood prediction and mitigation for use by the Alabama Emergency Management Agency (Sentar, 1996). Regardless of the complexity, the goal of ALERT systems is to provide advanced warning of flood events for a region by obtaining real-time hydrologic data with which to predict the high water levels and times of peak.

Although Glanville (Glanville, 1987) had created a HEC-1 model of the Squaw Creek basin for the purpose of flood prediction, officials for the City of Ames and Iowa State University (ISU) were uncomfortable relying on the model. The accuracy of almost any hydrologic model will be questioned without reliable ground verification via stream gages. In the case of Glanville's model, the only point of verification of the predicted peak discharge and time to peak was at the United States Geological Survey (USGS) stream gage near the damage centers at Lincolnway in Ames. Model verification at that point did not allow modlelers enough time to modify the model input parameters, create a more accurate prediction and still give local officials enough lead time to warn city residents of the need to sandbag or evacuate dwellings and business establishments.

To increase the warning lead time on the Squaw Creek basin during the 1993 flood event, City and University officials predicted the degree of flooding and time to peak in Ames by obtaining information about the degree of flooding upstream of Ames at Cameron School Road and county road R38. This information was gathered by persons who drove to the upstream locations, observed the amount of flow outside of the stream banks, and reported the information back to personnel at the City of Ames Water Plant or the University Department of Public Safety. Some of the persons obtaining information about the upstream locations had observed prior flood events on the Squaw Creek and Skunk Rivers which gave them a "feel" for how the flooding north of Ames would correspond to the degree of flooding which would be experienced at the damage centers of Ames. Observation of the flooding occurring upstream also allowed the time of peak of the flood to be approximated as the peak was seen upstream at Cameron School Road four to six hours before it was observed in the city damage centers, and the peak at R-38 was seen six to eight hours before the peak in the city was observed. These observations increased the local officials' confidence in the model's predictions, but still did not verify its accuracy as true verification could only occur at a stream gage location.

After the flood waters had receded, City of Ames personnel recorded the locations of high water marks left by the flood dirt and debris at various locations near and north of Ames. Two of these locations were located near the Cameron School Road (CSR) bridge on Squaw Creek and the Peterson Pits (PP) bridge on the Skunk River north of Ames. These locations were later surveyed to obtain elevations that corresponded to surveyed streambed elevations near the bridges. The data for the surveyed points are contained in Table 2.

Table 2. High Water Mark Elevations

Flood Event	Location	Elevation, ft.
July 9, 1993	CSR Machine Shed	924.1
July 13, 1993	CSR Ground	915.9
July 17, 1993	CSR Branch Marker	919.1
July 17, 1993	CSR Fence Rail	919.3
July 17, 1993	CSR Fence Post	919.7
July 9, 1993	PP Painted Sign Post	94.7

With cleanup of the flood debris completed and damage repair underway, representatives from Iowa State University, Iowa Department of Transportation (IDOT), Story County, and City of Ames met in late 1993 to discuss methods for avoiding another large-scale flooding disaster. It was determined that some of the flood damage could have been reduced or prevented had there been more advanced warning of the timing and degree of flooding that was to occur. To meet this objective, the representatives supported the creation of a flood warning system for the city of Ames. The computerized basin modeling project on which this thesis is based is part of that warning system.

PROJECT OBJECTIVES

The objective of this project is to revise, calibrate and verify the HEC1 computer model for the Squaw Creek basin first developed in 1987 by Thomas D. Glanville using recent flood event precipitation and streamflow data. The model is to be used as part of a larger computer model encompassing both Squaw Creek and Skunk River basins. The larger model with peripheral data collection systems for precipitation and river stages will be a component of a flood warning system for the City of Ames, IA.

SCOPE OF STUDY

The Squaw Creek basin modeling project consists of five parts:

1. Creation of stage-discharge curves for stream gages placed on the Skunk River and Squaw Creek by the City of Ames.
2. Revision of the model created by Glanville in 1987 in order to provide nodes at the locations for the above-mentioned stream gages.
3. Calibration and verification of the revised model using data from 1993 and 1994 flooding events.
4. Location of sources of real-time precipitation data for use as input to the HEC-1 model.
5. Facilitation of the model's use in a larger computer model encompassing both Squaw Creek and Skunk River basins.

CREATION OF STAGE-DISCHARGE CURVES FOR STREAM GAGES LOCATED ON SQUAW CREEK AND SKUNK RIVER

Background

The HEC-1 model created by Glanville in 1987 (Glanville, 1987) is a model that can predict the time of peak and peak discharge for major floods that occur on the Squaw Creek basin. As noted earlier, officials at Iowa State University and the City of Ames have been uncomfortable using the model up to this point because of the possibility that the model might not produce accurate results. Local officials were concerned about legal liabilities that might result if the degree of flooding was over or under-predicted. This concern is shared by many local officials in areas where flash flooding is a strong possibility in any given year. (Owen, 1980, p. 231-237)

A system of river gages upstream from Ames was an answer to the need for model verification during flooding events. Two gages were placed upstream of Ames on Squaw Creek. One gage is located on the bridge over Squaw Creek for county road E18. The other is located on the bridge over Squaw Creek for Cameron School Road. Two additional gages were placed upstream of Ames on the Skunk River. The complete flood warning system for Ames would also include a computer model for the Skunk River watershed which would need verification. The Skunk River gages are located on bridges over the Skunk River for county road E18 and Peterson Pits Road. Figure 1 shows the gage locations.

The HEC-1 model creates hydrographs in terms of flows (cubic feet/second). Stream gages produce output in terms of stream depth or depth to the water surface depending on the setup of the gage. Clearly there was a need for stage-discharge curves for the gages in order to be able to use the gages for model verification purposes.

Procedure

PCVAL, an unpublished computer program developed by the Iowa Department of Transportation (IDOT) (Iowa Department of Transportation, 1987), was used to produce the stage-discharge curves. Little documentation is available on the program, however, it is used by the Office of Bridge Design at the IDOT and by Iowa county engineers to develop stage-discharge curves for design purposes. The program is based on Manning's equation (Barrett, 1996).

$$Q = (1.49/n)\, A\, R^{2/3} S^{1/2}$$

where:
Q = stream flow, cfs
n = Manning's roughness coefficient
A = channel cross-sectional area, ft^2
R = channel hydraulic radius, ft
S = slope of the energy grade line
= slope of the water surface or channel bottom for uniform flow

Input to the program included stream valley cross-section elevations, stream slopes, and stream valley Manning's roughness coefficients.

Stream Valley Cross-section Elevation Determination

Stream valley cross-sections for each gage location were determined by a combination of surveying the streambed and using bridge construction plans for the valley.

Bridge plans for the four bridges were obtained from the Story and Boone county engineers. The plans for the E18 bridge over Squaw Creek, the Cameron School Road bridge over Squaw Creek and the E18 bridge over the Skunk River contained a grid of stream valley elevations. The plans for the Peterson Pits bridge over the Skunk River did not contain stream valley elevations. On each map where valley elevations were available, two lines were drawn perpendicular to the direction of flow in the stream, one located upstream of the bridge and one located downstream of the bridge. The elevations listed along these lines were plotted vs. distance along the lines to develop representative valley cross-sections for the areas surrounding the bridges. Two cross-section lines were used because the streams meander near the bridges. The cross-sections upstream and downstream of the bridges are not necessarily the same due to the meandering and the surrounding land use and topography. For example, in the case of Cameron School Road, upstream the stream basin contains gullies and timberland, downstream the basin contains pastureland. The stream valley cross-section elevations obtained are tabulated in Tables A1 through A3 in Appendix A. Plots of the valley cross-sections from the bridge plans are pictured in Figures 2 through 7. The actual streambed in these plots is often one or two points.

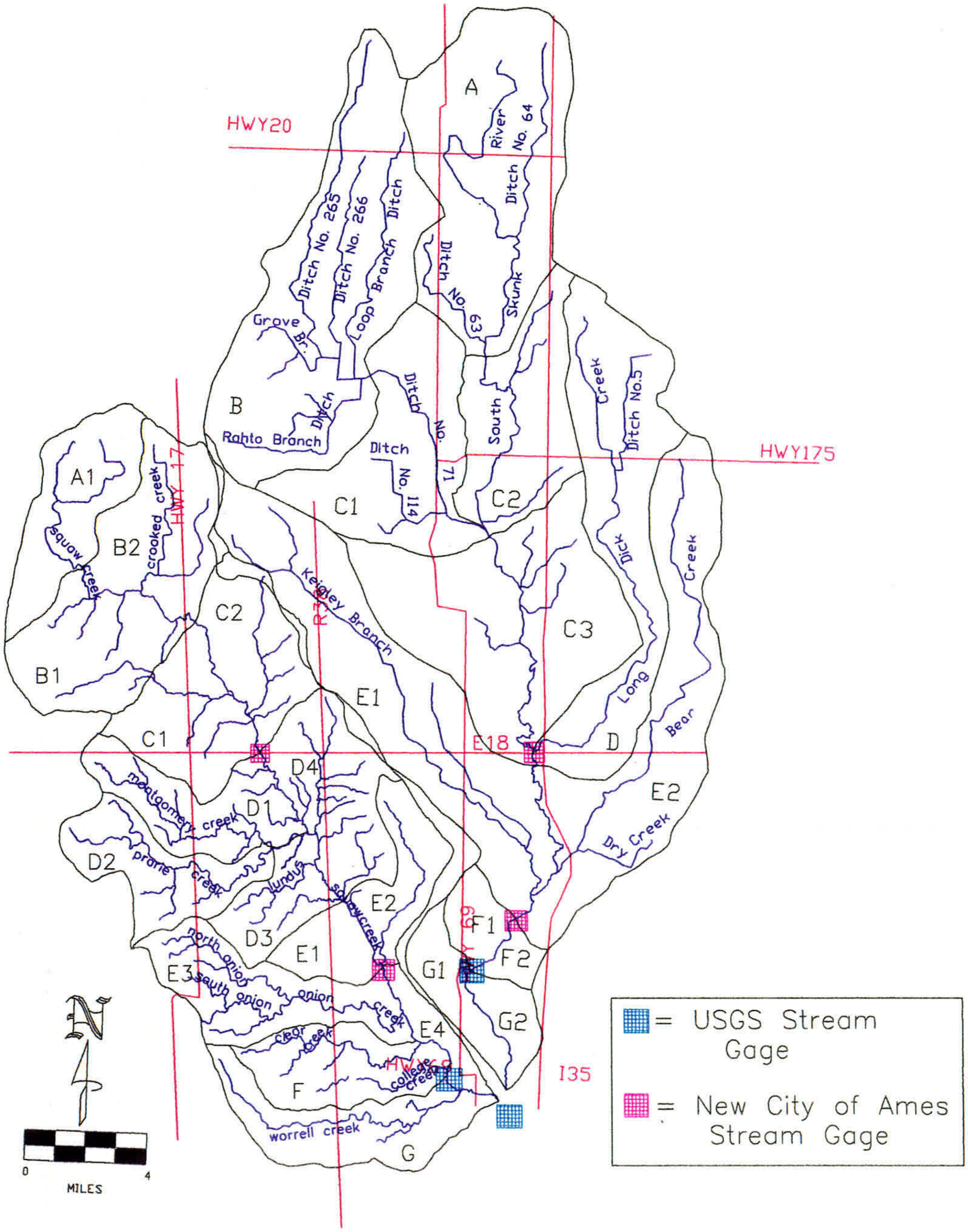

Figure 1. Map of Stream Gage Locations on Squaw Creek and Skunk River

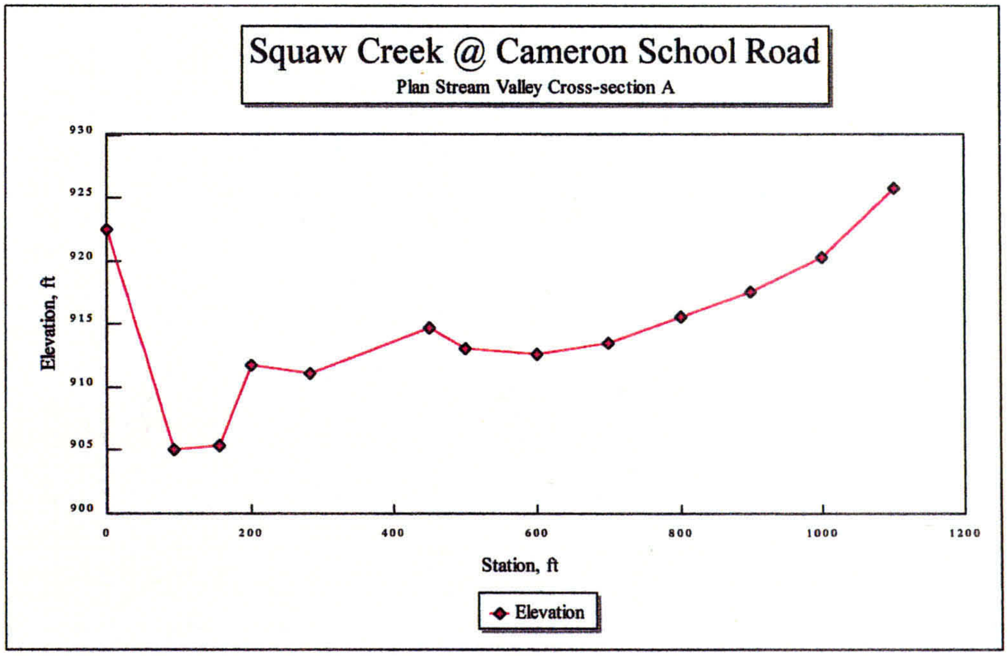

Figure 2. Squaw Creek at Cameron School Road Stream Valley Cross-section A

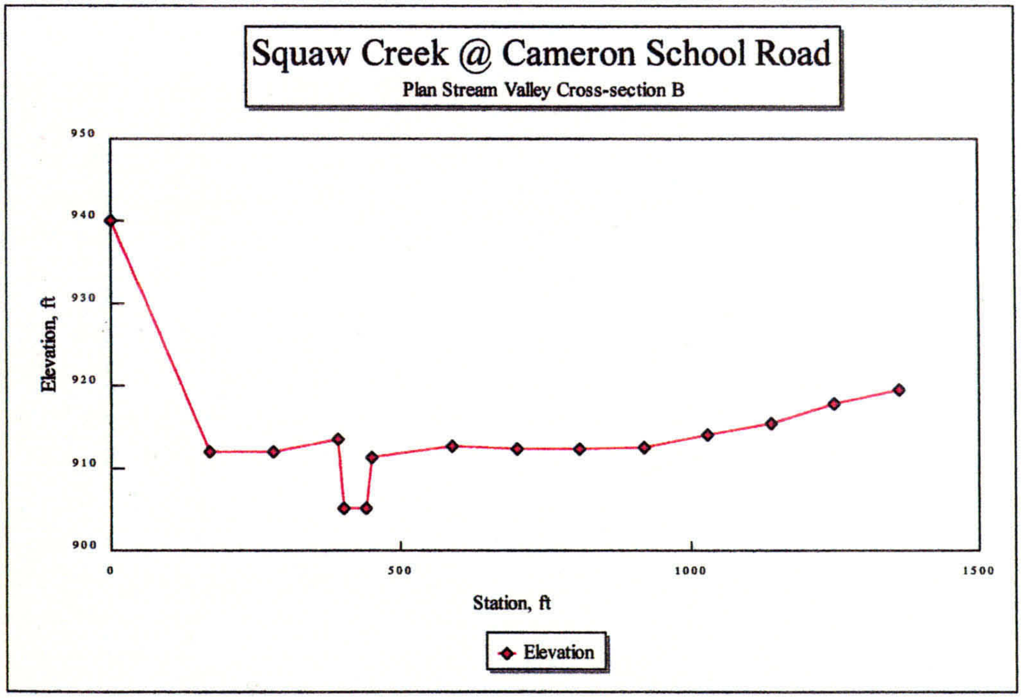

Figure 3. Squaw Creek at Cameron School Road Stream Valley Cross-section B

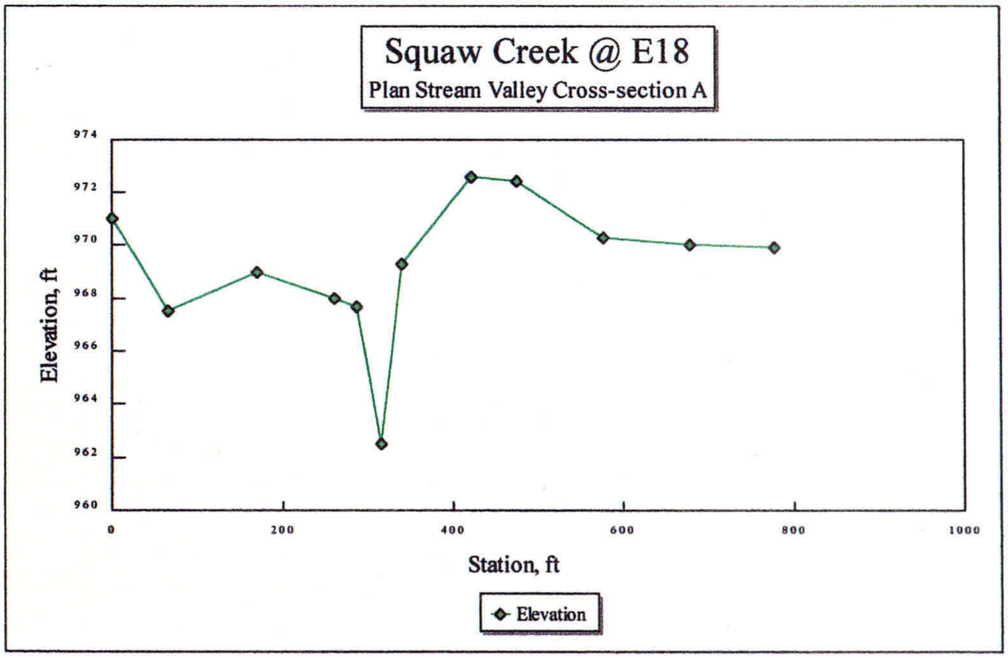

Figure 4. Squaw Creek at E18 Stream Valley Cross-section A

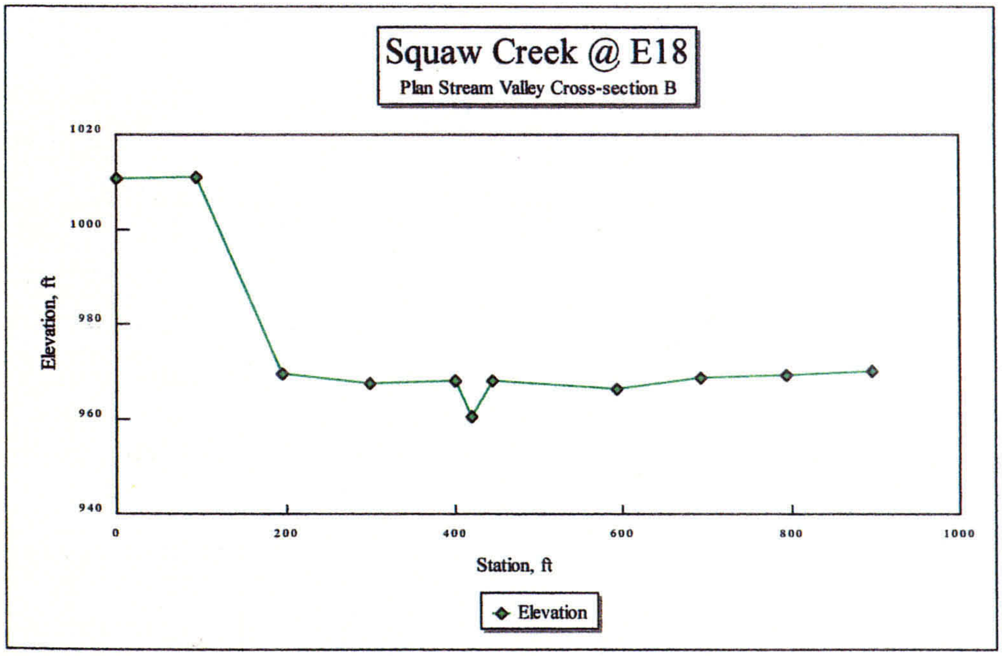

Figure 5. Squaw Creek at E18 Stream Valley Cross-section B

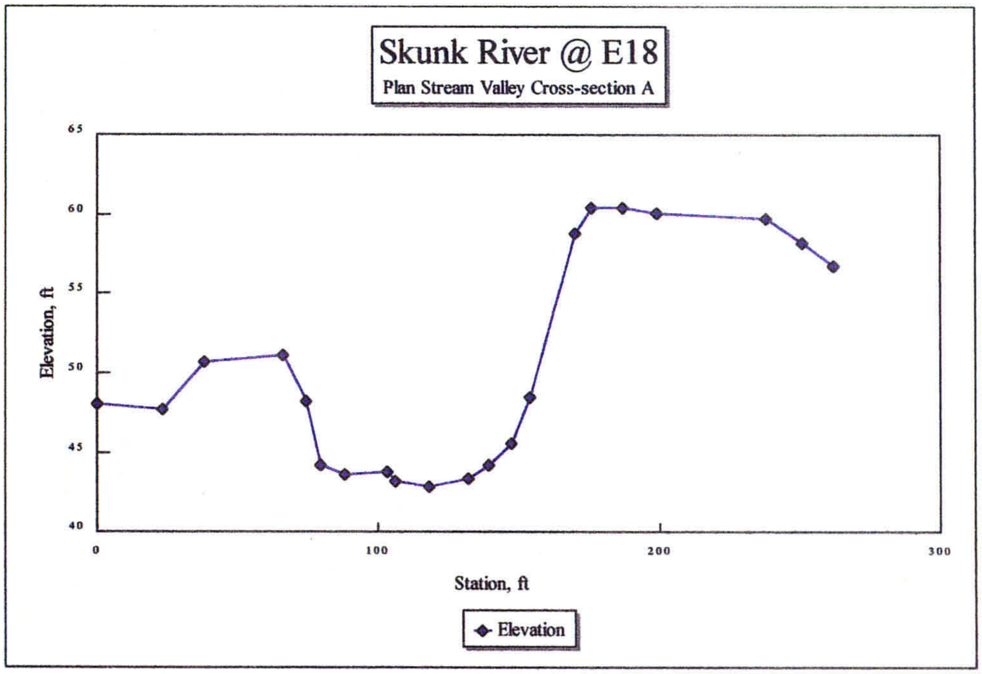

Figure 6. Skunk River at E18 Stream Valley Cross-section A

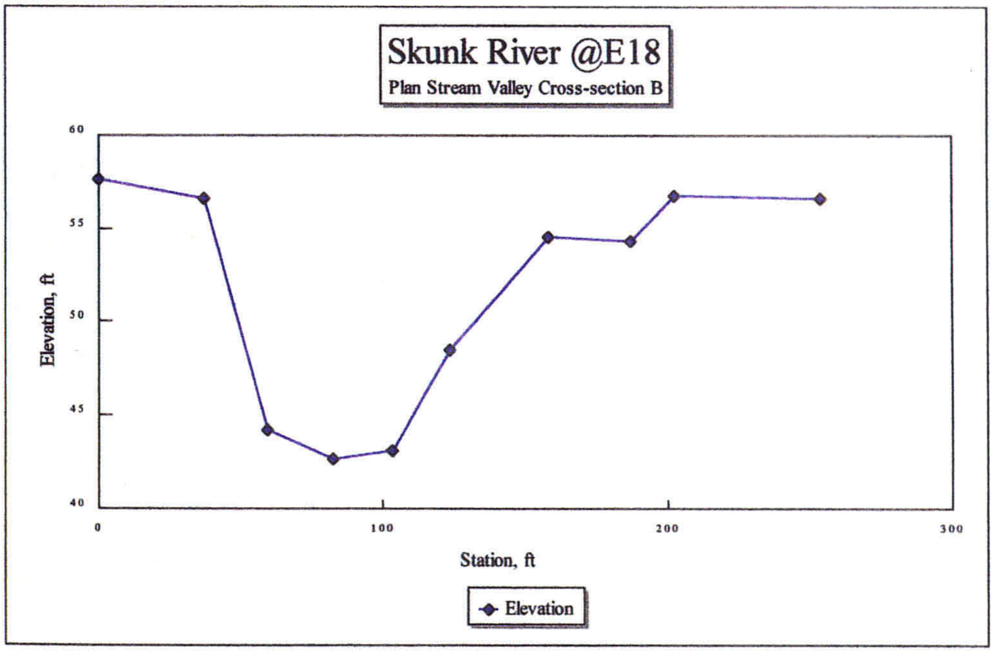

Figure 7. Skunk River at E18 Stream Valley Cross-section B

Three of the bridge streambeds were conducive to surveying at the time of this study, Squaw Creek at E18, Squaw Creek at Cameron School Road and Skunk River at Peterson Pits bridge. The streambed cross-section elevations obtained from the surveys are tabulated in Tables A4 through A6 in Appendix A. Plots of the surveyed streambed cross-sections are shown in Figures 8 through 10. The surveyed data focused on the streambeds and did not include much of the surrounding land, although the surrounding area would be part of the floodway in a flooding event.

Stream Slope Determination

Plans for the Cameron School Road bridge had the Squaw Creek stream slope listed on the plans. Stream slopes for the other three gage locations had to be determined by surveying (Peterson Pits) or from topographic maps (Peterson Pits, E18 over Squaw Creek, E18 over Skunk River). The slopes used in the PCVAL calculations are listed at the bottom of Tables A1 through A4 in Appendix A.

The two stream slopes determined for Peterson Pits bridge were quite different. The slope obtained while surveying was obtained by surveying the elevation of the water surface 326 feet upstream and 95 feet downstream of the bridge. Being off by even one tenth of a foot elevation in a 400 foot length could cause a difference of 1.3 feet/mile in slope. A longer distance would have been preferable, but was not feasible due to the heavy brush and stream meandering. Because the water surface elevation could easily have been inaccurate by one-tenth of a foot and the fact that the slope determined from the topographic maps more closely matches that from the Cameron School road plans, the stream slope determined by using the topographic map would be preferred.

Roughness Coefficient Determination

Manning's roughness coefficients, n, for the stream gage locations were determined by comparing the observed valley features at the gage locations with the descriptions and pictures in Chow's Open Channel Hydraulics book (Chow, 1959). A summary of roughness coefficient values and descriptions related to those values is shown in Table 3. Roughness coefficients used for the PCVAL program for the four gage locations are listed on Tables A1 through A6 in Appendix A.

Results

Stream valley cross-section elevations, stream slopes and roughness coefficients were entered into the PCVAL program (Iowa Department of Transportation, 1987). Each set of cross-section elevations, corresponding stream slopes and channel roughness

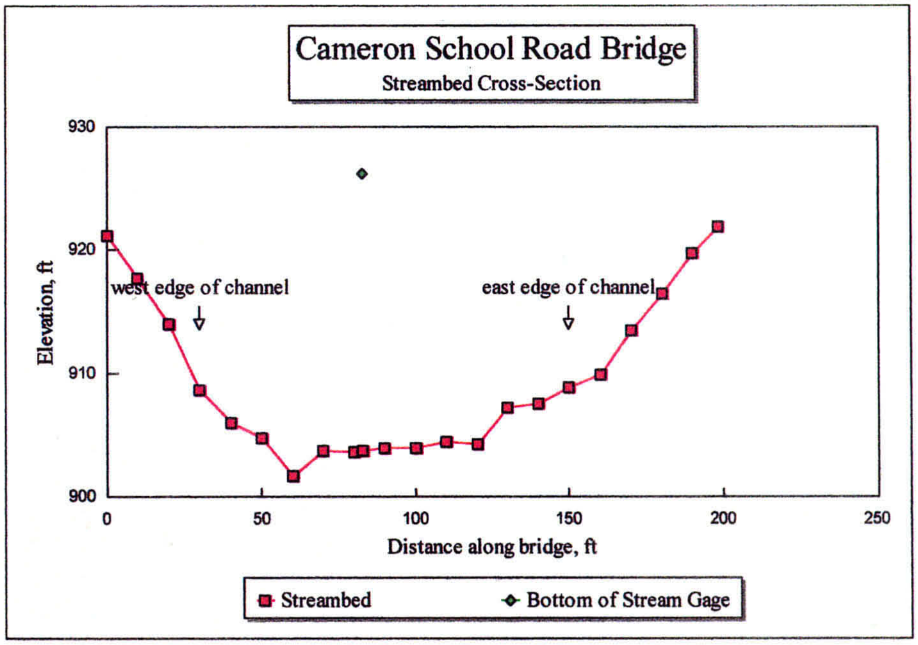

Figure 8. Surveyed Cameron School Road Bridge Streambed Cross-section

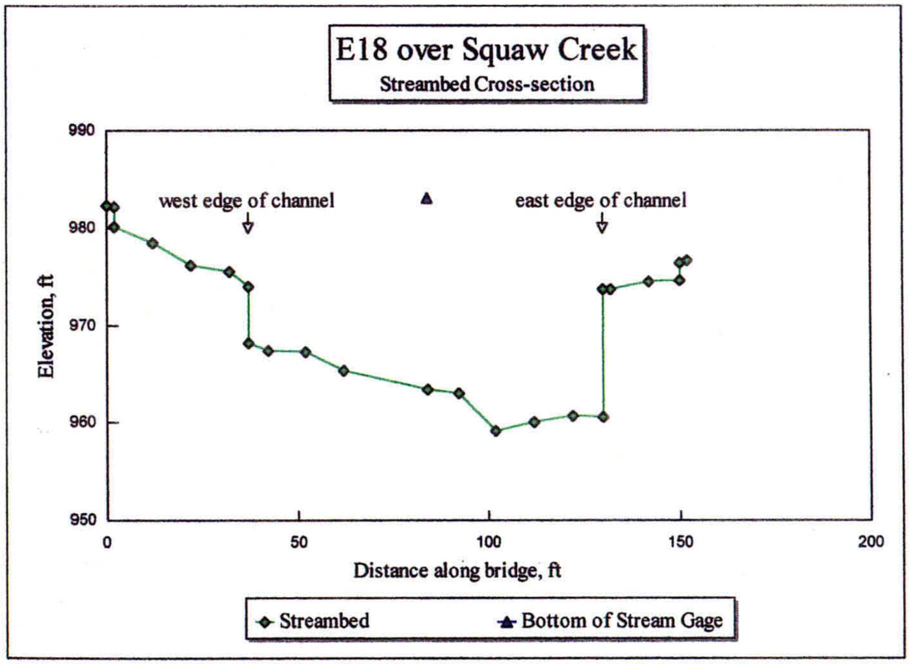

Figure 9. Surveyed E-18 over Squaw Creek Streambed Cross-section

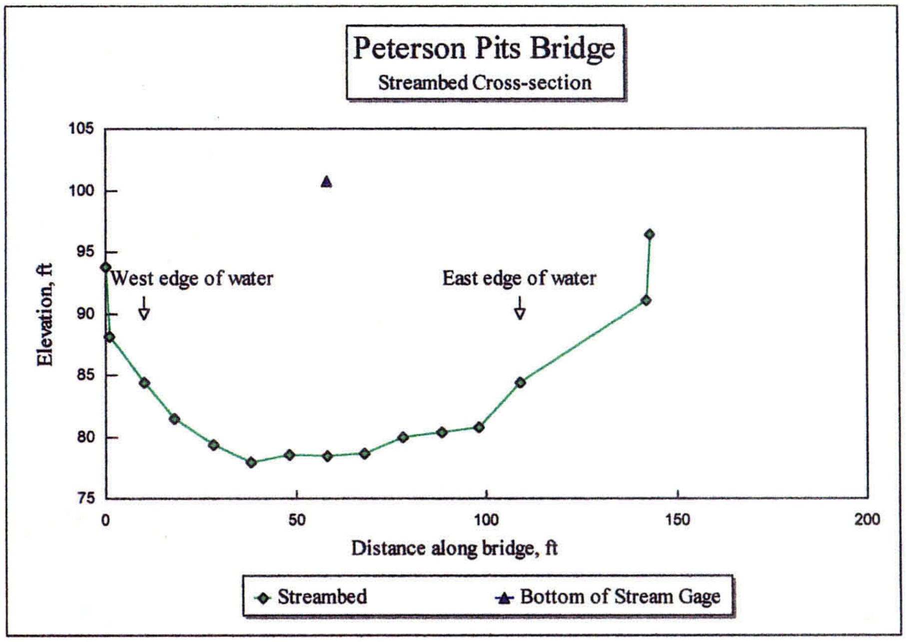

Figure 10. Surveyed Peterson Pits Bridge Streambed Cross-section

Table 3. Roughness Coefficient Values and Descriptions

Description	Roughness Coefficient n
Major Stream, top width at flood stage >100 feet	0.035
Pasture, no brush	0.037
Cultivated, no crop	0.032
Cultivated, row crop	0.035
Brush, light brush and trees	0.050
Brush, light to medium brush	0.075
Brush, medium to dense brush	0.100
Timber, little undergrowth	0.100

coefficients was entered individually. A set of stage-discharge curves was obtained for each gage location and graphed. The resulting PCVAL output data and graphs are shown in Tables B1 through B5 in Appendix B and Figures 11 through 14. In order to determine a better estimate for discharge flows at Cameron School Road for the City of Ames surveyed high water marks listed in Table 2, road elevations from the bridge plans were added to the surveyed streambed elevations to produce a stage-discharge curve with higher elevation values. This curve is also depicted on the Cameron School Road stage-discharge graph Figure 12.

For use in comparison of predicted versus actual stream flows from the HEC-1 model, the stage-discharge curves generated using surveyed elevations would be preferred. As can be seen by comparing the surveyed streambed data plots versus the stream valley cross-section data plots, the surveyed elevations for the streams have shorter distances between readings than those obtained from the bridge plan valley cross-sections. With shorter distances between readings, it is more likely that the true low point of the streambed will be included in the generation of the stage-discharge curves. The surveyed data are also more current. Flood events, water erosion and valley development could have altered the true valley cross-sections since the time the plans for the bridges were produced. The only gage for which surveyed elevation data are unavailable is the E18 over the Skunk River gage. It is hoped that the streambed at that location will be surveyed in the future and a more accurate stage-discharge curve determined .

After the stream gages had been installed at the bridge sites, the elevations of the bottoms of the gages were also surveyed for the three bridges where surveying was feasible. The elevations of the stream gage bottoms are listed in Table 4 and are indicated

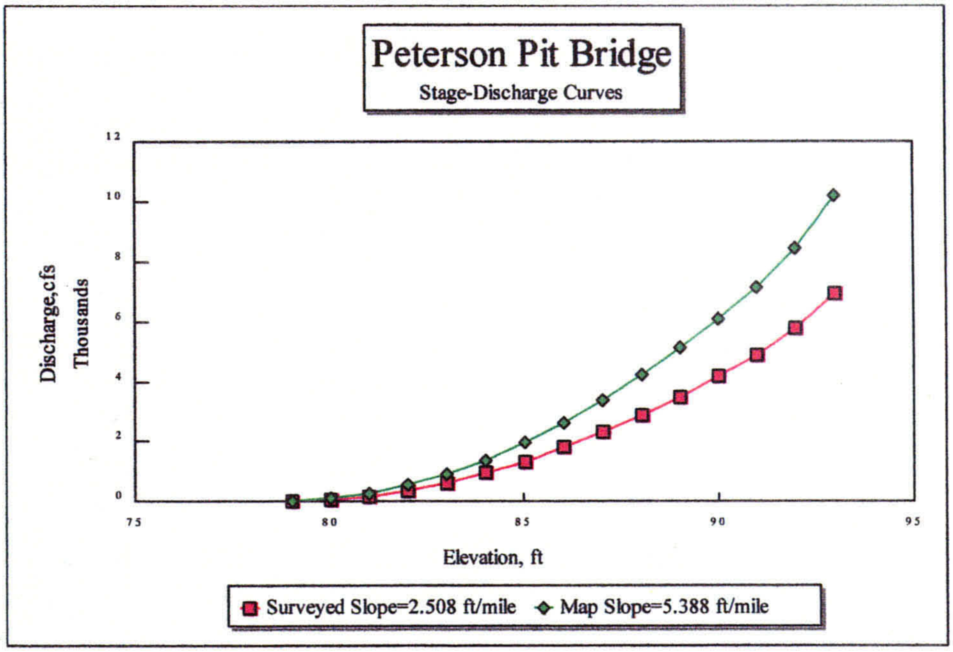

Figure 11. Peterson Pits Bridge Stage-Discharge Curves

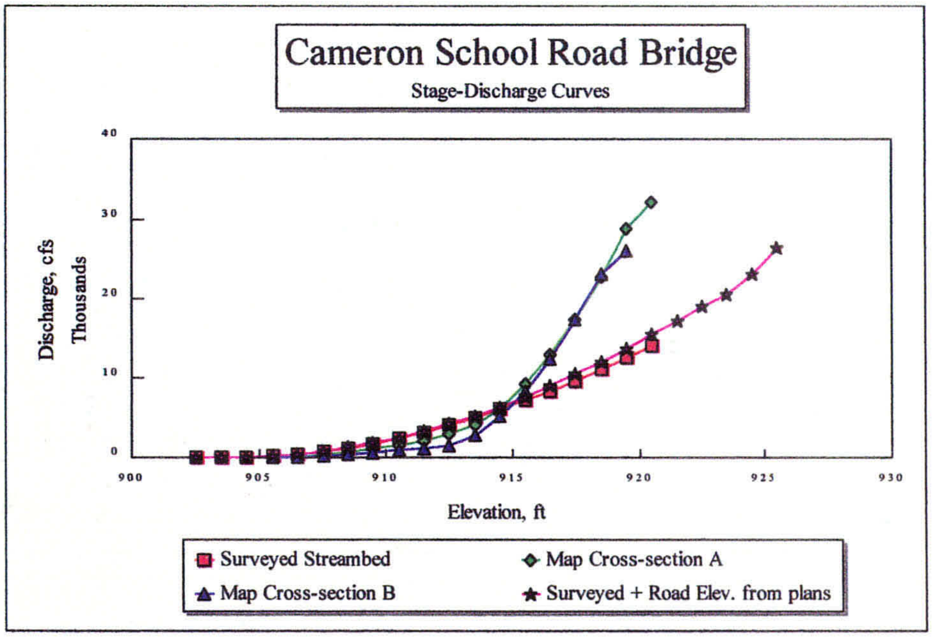

Figure 12. Cameron School Road Bridge Stage-Discharge Curves

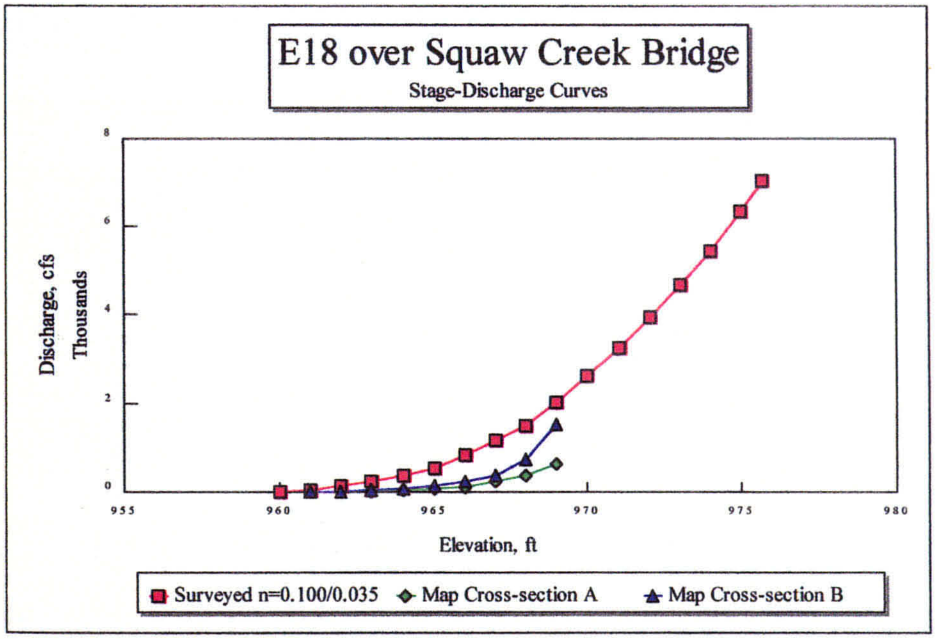

Figure 13. E-18 over Squaw Creek Bridge Stage-Discharge Curves

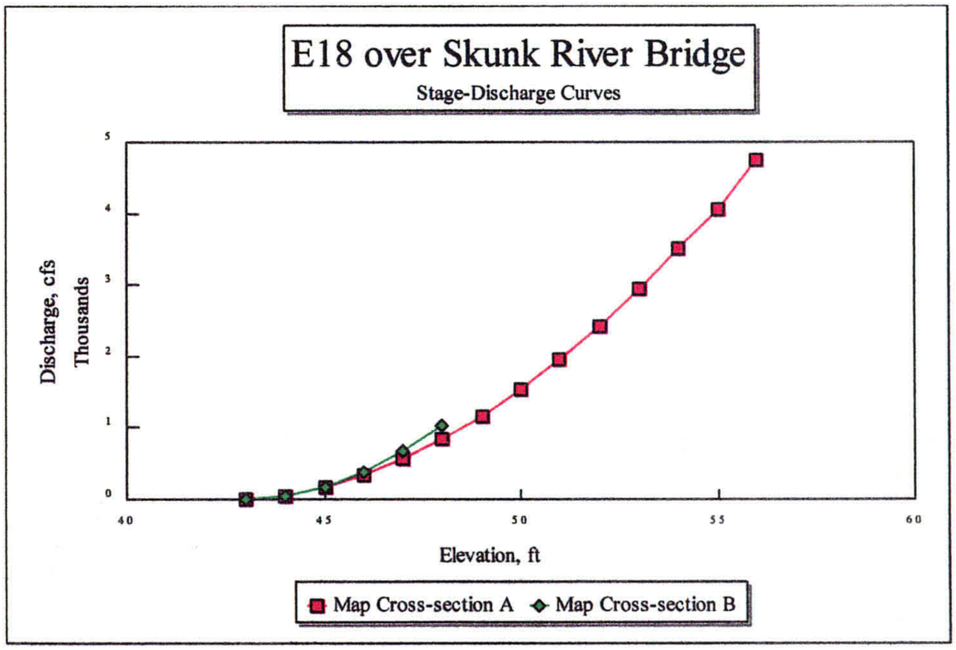

Figure 14. E-18 over Skunk River Bridge Stage-Discharge Curves

on the streambed cross-section plots (Figures 8 through 10). The stage-discharge curves for Cameron School Road and Peterson Pits bridge were used to estimate the peak flow at those locations during the flood events of 1993 from the surveyed high water marks listed in Table 2. The estimated flows for those events are listed in Table 5. These flows were used in the calibration and verification of the revised HEC-1 model as described later in this report.

Stage-discharge data for the United States Geological Survey (USGS) stream gage at Lincolnway in Ames were obtained from the USGS. These data were used with flood hydrographs also obtained from the USGS to calibrate and verify the HEC-1 model as described later in this report. A copy of the Lincolnway USGS gage stage-discharge data is included in Appendix B.

Table 4. Stream Gage Bottom Elevations

Stream Location	Elevation, ft
Cameron School Road bridge	926.2
Peterson Pits bridge	100.78
E18 over Squaw Creek bridge	983.12

Table 5. Flood Event Discharges from Stage-Discharge Curves

Flood Event	Location [a,b]	Elevation (ft)	Discharge (cfs)	USGS discharge (cfs)
July 9, 1993	CSR Machine Shed	924.1	22609	24300[c]
July 13, 1993	CSR Ground	915.9	8116	8660[c]
July 17, 1993	CSR Branch Marker	919.1	12863	11090[c]
July 17, 1993	CSR Fence Rail	919.3	13188	11090[c]
July 17, 1993	CSR Fence Post	919.7	13855	11090[c]
July 9, 1993	PP Painted Sign Post	94.7	8985	8980[d]

a. CSR = Cameron School Road b. PP = Peterson Pits Bridge

c. USGS gage at Lincoln Way d. USGS gage on the Skunk River North of Ames

REVISION OF SQUAW CREEK HEC-1 MODEL

Background

Glanville gave a detailed description of his procedure for dividing the Squaw Creek drainage basin into thirteen subbasins based on drainage data obtained from USGS topographic maps and drainage district maps (Glanville, 1987 pp.64-65). The delineation worked well from the standpoint of storm tracking and basin runoff response. However, when the new stream gages were put in at the E-18 over the Squaw Creek and Cameron School Road bridges, subbasin nodes were needed in the model at those locations in order to compare actual basin response with predicted model response.

Procedure

Subdivision of Squaw Creek Basin and Subbasin Area Determinations

The Glanville model had a subbasin node at the location of the stream gage on the E-18 over the Squaw Creek bridge (location where subbasins C1 and C2 entered stream hydrograph), but a node needed to be created at the location of the Cameron School Road bridge. As the original maps used by Glanville to make the model subdivisions were unavailable, the process had to be redone on a new set of USGS maps.

The basin subdivisions were located on the maps. An attempt was made to match Glanville's basin delineations as closely as possible. Subbasins E1 and E2 were divided at logical locations from a drainage standpoint to create the necessary node for the Cameron School Road bridge stream gage. The final subbasin division is shown in Figure 15. Cameron School Road bridge is located where subbasins E1 and E2 enter the stream hydrograph.

The subdivided areas were planimetered from the USGS topographic maps. The total planimetered area is within 5% of the literature value of 227 square miles (U.S. Department of the Interior, 1974). The subbasin areas used in the revised HEC-1 model are listed in Table 6. A schematic of the revised Squaw Creek basin model is shown in Figure 16.

Subbasin SCS Curve Number Determination

Glanville also determined appropriate SCS curve numbers for each of the subbasins. (Glanville, 1987, pp.72-77) The values determined for each of the subbasins were used

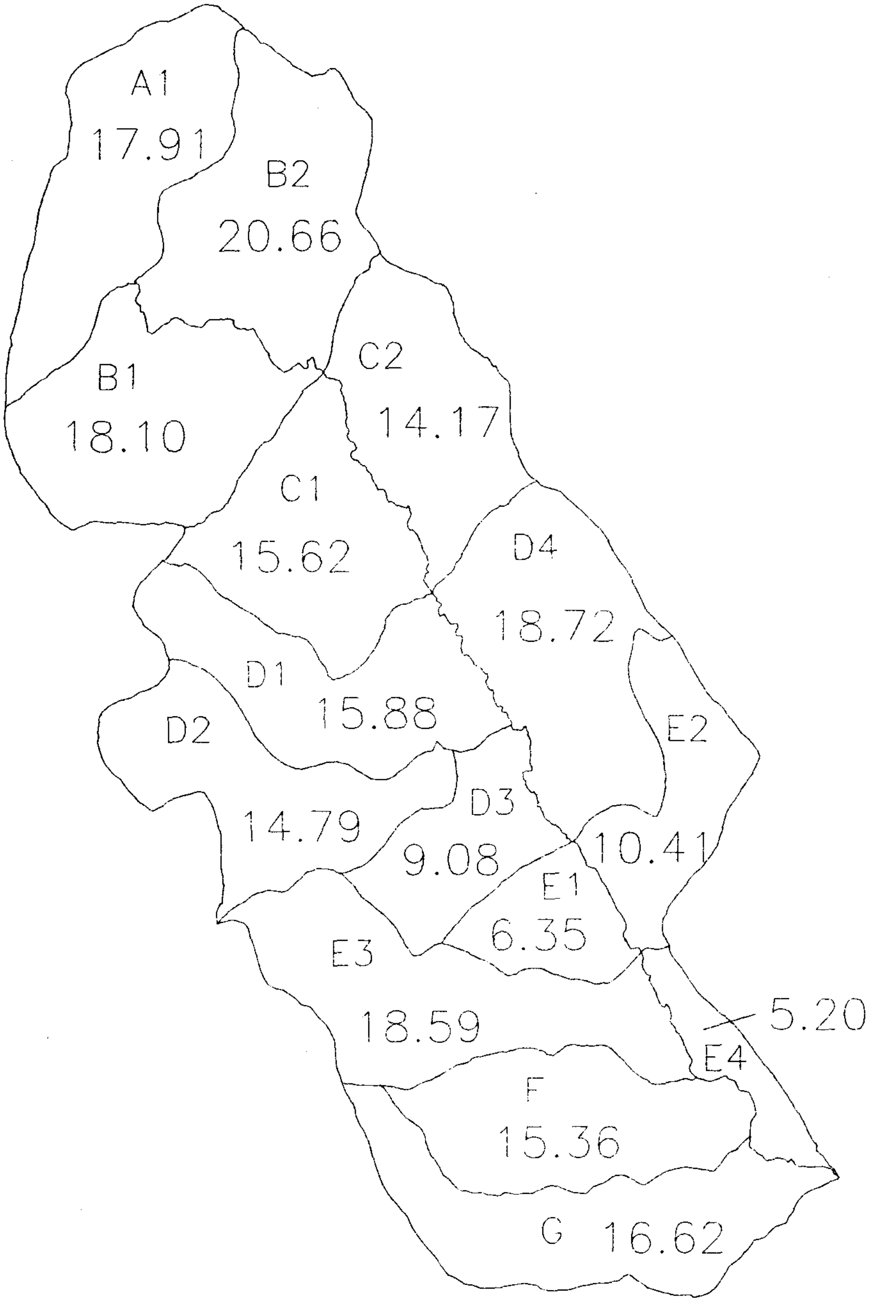

Figure 15. Map of Squaw Creek Basin Subdivisions and Areas

in the revised HEC-1 model. The SCS curve numbers for the old subbasin E1 were used for subbasins E1 and E3 and the SCS curve numbers for the old subbasin E2 were used for subbasins E2 and E4 in the revised HEC-1 model.

It was also noted in the calibration of the revised HEC-1 model that often a curve number associated with an antecedent moisture condition between Antecedent Moisture Condition (AMC) II and AMC III more closely matched the actual data. Therefore, a SCS curve number corresponding to an AMC II.5 was developed by averaging the curve numbers associated with AMC II and AMC III. It is possible to do this because Antecedent Moisture Conditions and the associated curve numbers represent the physical reality of soil moisture. True soil moisture occurs on a continuum that is not easily represented by discrete values. At any given time actual moisture conditions on a watershed could fall somewhere in between the values given for any discrete designation. Therefore, the curve numbers that most closely match the actual antecedent moisture condition on the basin could be used even if they fall in between those listed for the discrete designation of AMC II or AMC III. The discrete SCS curve numbers used as

Table 6. Squaw Creek HEC-1 Model Subbasin Areas

Subbasin Label	Subbasin Area square miles
A	17.91
B1	18.10
B2	20.66
C1	15.62
C2	14.17
D1	15.88
D2	14.79
D3	9.08
D4	18.72
E1	6.35
E2	10.41
E3	18.59
E4	5.20
F	15.36
G	16.62
Total Area	217.46

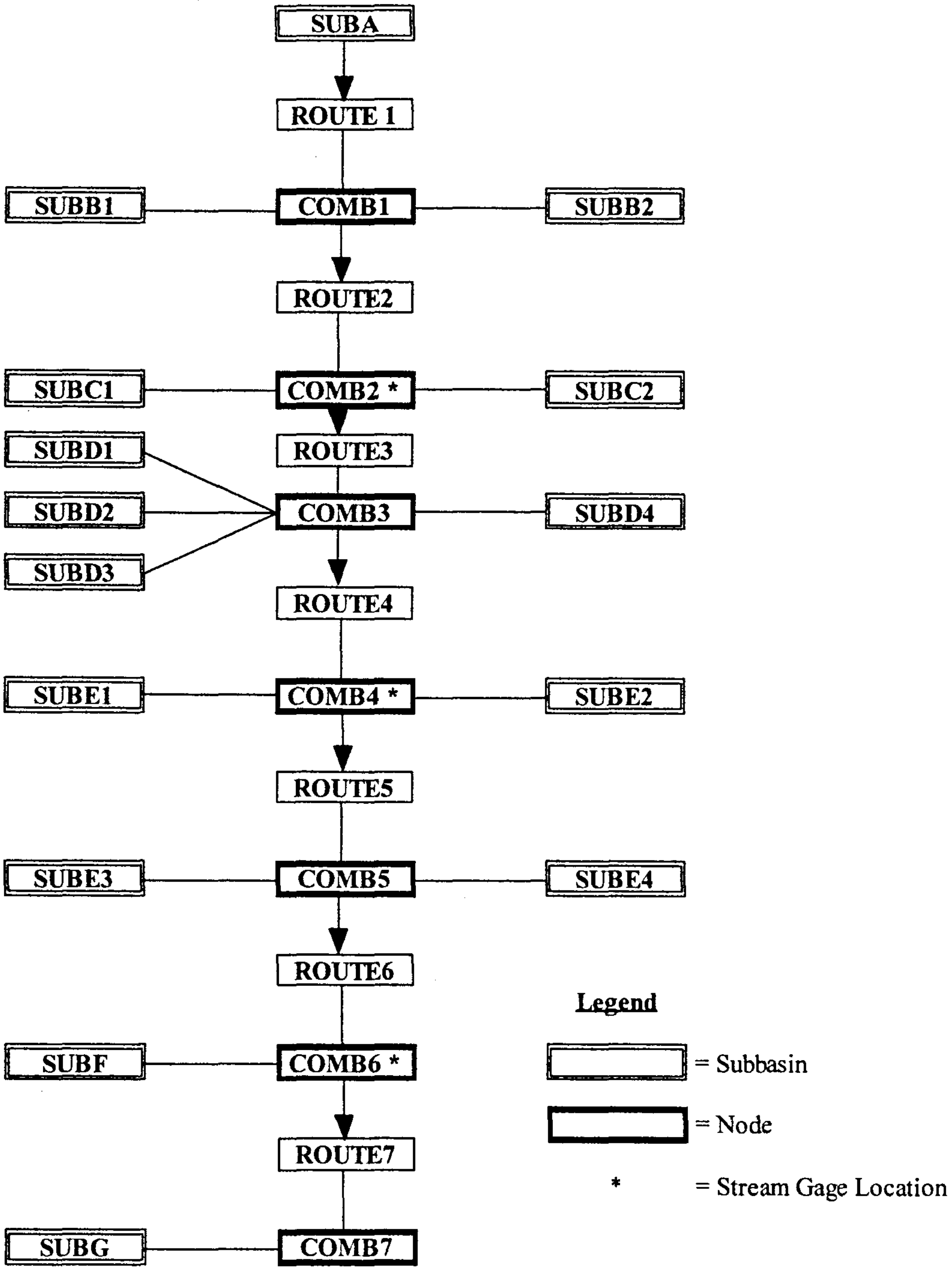

Figure 16. Schematic Diagram of the Squaw Creek HEC-1 Basin Model

starting points for representing the true antecedent moisture condition of the basin in the calibration and verification of the revised model are listed in Table 7.

Subbasin Lag Time Determination

Glanville described the determination of subbasin lag times to be used in the HEC-1 model (Glanville, 1987, pp. 80-89). His determination of lag time using times of concentration based on overland and channel flow approximations and the application of the SCS lag time equation gave the values shown in Table 8 as the Glanville Model lag times. It should be noted that the value given for E1 was for the combined area of E1 and E3 in the revised model, and the value given for E2 was for the combined area of E2 and E4 in the revised model. Glanville used Mitchell's Method as a check of the lag time values obtained by the SCS lag time calculations. He determined that the values obtained by the two estimating methods compared fairly well (Glanville, 1987, p. 92). The empirical equation used for Mitchell's Method is:

$$T_{lag} = 1.05\ A^{0.60}$$

where:

T_{lag} = Basin lag time in hours
A = Basin drainage area in square miles

The value calculated by the Mitchell's Method equation was used as an initial lag time value for the revised HEC-1 model lag times for subbasins E1, E2, E3 and E4. All other initial lag times were those from the original Glanville model.

During the model calibration process, the lag times were modified by iterative model adjustments to better fit actual stream routing lag time data. A close estimate of actual stream routing lag times was obtained from City of Ames Water and Pollution Control Department River Readings documents for the July 13, 1993 and the July 17, 1993 flood events. City of Ames personnel documented on those records the times at which the flood waters at Cameron School Road appeared to begin receding (City of Ames, 1993). Actual stream routing lag times were also obtained from stream gage readings during the 1994 high water event which occurred following the installation, but not the calibration, of the upstream stream gages at Cameron School Road and E18 on Squaw Creek (City of Ames, 1994). The lag times used in the final revised version of the HEC-1 model are listed in Table 8. These may need to be adjusted again as future flooding or high water events provide additional data.

Table 7. Squaw Creek HEC-1 Model Subbasin SCS Curve Numbers

Subbasin Label	AMC I	AMC I.5	AMC II	AMC II.5	AMC III
A	64	73	81	87	92
B1	64	73	81	87	92
B2	64	73	81	87	92
C1	60	69	78	84	90
C2	63	72	80	85	91
D1	62	71	79	85	91
D2	63	72	80	85	91
D3	63	72	80	85	91
D4	62	71	79	85	91
E1	60	69	78	84	90
E2	62	71	79	86	92
E3	60	69	78	84	90
E4	62	71	79	86	92
F	59	68	77	83	89
G	59	68	77	83	89

Theissen Polygon Determination

The Squaw Creek basin responds rapidly to rainfall events. In most flood events, the length of time between the most intense rainfall and the peak flooding at Lincoln Way in Ames was less than 24 hours. Therefore, precipitation data were needed in hourly or 15-minute intervals in order to be useful for modeling on the basin. Both 15-minute and hourly precipitation data sets were experimented with during the model calibration. It was found that there was little or no increase in model accuracy with 15-minute data, therefore, calibration and verification were completed utilizing hourly precipitation data.

Hourly precipitation data from the National Climatic Data Center were available for only one location on the basin, Ames 8WSW. There were three other locations that were within a few miles of the basin, Ogden, Story City, and Webster City. These four rain gage locations were used to create a Theissen polygon for the Squaw Creek basin. It should be noted that none of these rain gages is in the northwest quadrant of the basin. This is a cause for concern as most of the storm events leading to severe flooding on the Squaw Creek are storms that track from northwest to southeast. Without precipitation data from the northwest, the model may not adequately predict the true degree of flooding. The lack of precipitation tracking from the northwest was the very problem Glanville encountered in calibrating the model with the 1975 flood event. He used data

Table 8. Squaw Creek HEC-1 Model Subbasin Lag Times

	Area	Glanville	Mitchell's Method		Used in
Subbasin	(Miles^2)	Model	Lag Time	Range	Revised Model
A	17.91	5.9	5.93	3.71 - 8.15	6.3
B1	18.10	7.9	5.97	3.74 - 8.20	7.9
B2	20.66	4.9	6.46	4.04 - 8.88	6.8
C1	15.62	2.9	5.46	3.42 - 7.51	5.0
C2	14.17	3.1	5.15	3.23 - 7.08	5.2
D1	15.88	9.5	5.52	3.45 - 7.58	9.5
D2	14.79	3.7	5.29	3.31 - 7.26	5.3
D3	9.08	5.0	3.94	2.47 - 5.42	5.0
D4	18.72	2.3	6.09	3.81 - 8.37	5.7
E1	6.35	4.7	3.18	1.99 - 4.37	1.0
E2	10.41	8.0	4.28	2.68 - 5.88	4.0
E3	18.59		6.06	3.80 - 8.33	4.7
E4	5.20		2.82	1.77 - 3.88	4.0
F	15.36	6.3	5.41	3.39 - 7.43	6.3
G	16.62	5.6	5.67	3.55 - 7.79	5.2

provided by an area farmer to correct the deficiency, but that type of data is no longer available.

The hourly precipitation Theissen polygon is shown in Figure 17. The corresponding polygon area for each of the subbasins is tabulated in Table 9. These are the weighted precipitation values used for the revised HEC-1 model.

Description of Model Inputs

An example of a HEC-1 model input file can be found in Appendix C followed by a description of the file inputs and acceptable values for the input parameters.

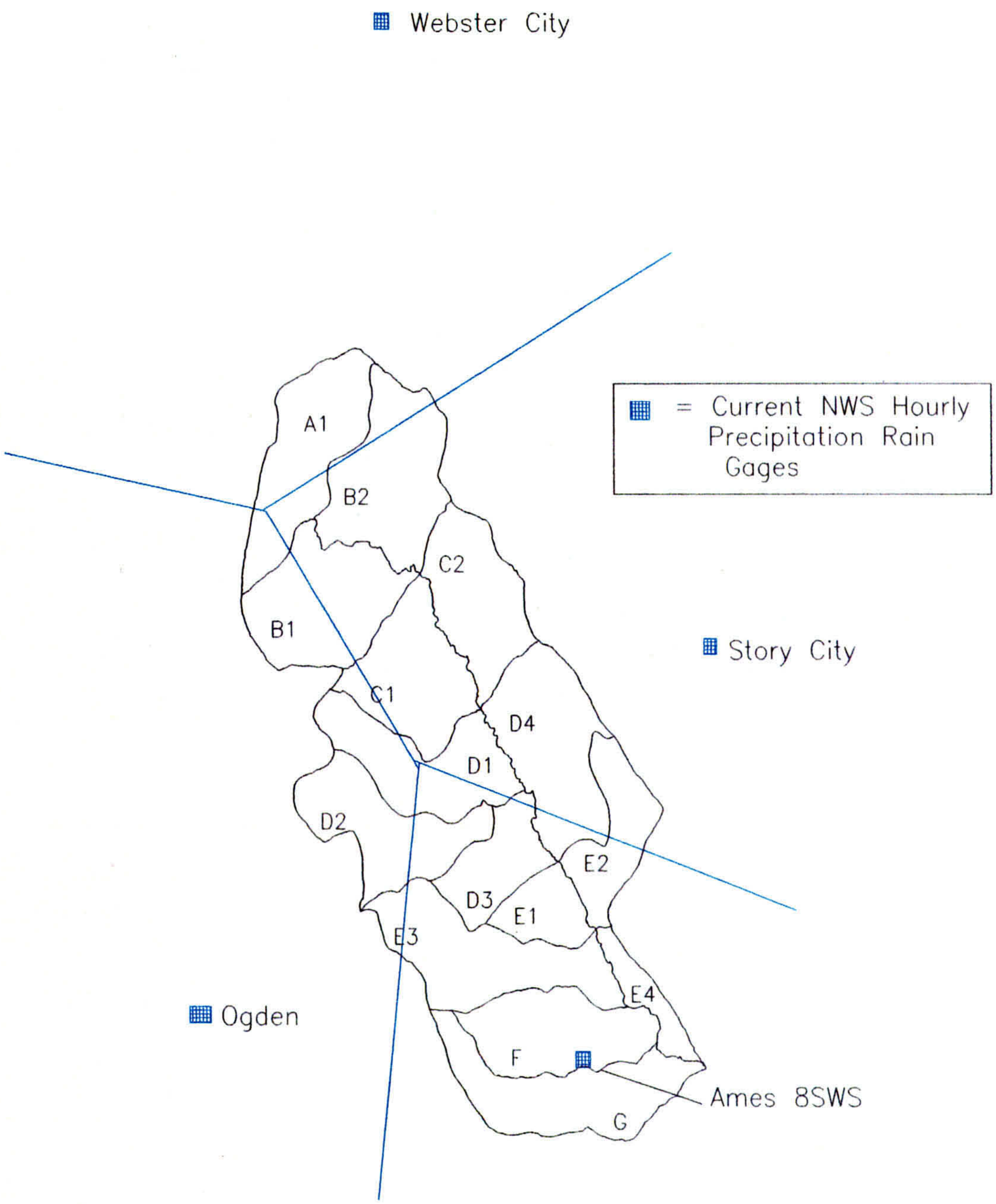

Figure 17. Map of Squaw Creek Basin Theissen Polygon using NWS Hourly Precipitation Gages

Table 9. Squaw Creek HEC-1 NWS Hourly Precipitation Gages Theissen Polygon Area Percentages

		Percent of Area in Polygon Section			
Subbasin	Area square miles	Ames 8WSW (43)	Story City (38)	Webster City (11)	Ogden (10)
A	17.91		0.22	85.26	14.52
B1	18.10		55.30		44.70
B2	20.66		64.96	35.04	
C1	15.62		98.21		1.79
C2	14.17		100.00		
D1	15.88	35.58	44.46		19.96
D2	14.79	54.77			45.23
D3	9.08	96.26	3.74		
D4	18.72	11.43	88.57		
E1	6.35	100.00			
E2	10.41	48.32	51.68		
E3	18.59	100.00			
E4	5.20	100.00			
F	15.36	100.00			
G	16.62	100.00			
Total	217.46	42.50	37.70	10.10	9.70

CALIBRATION AND VERIFICATION OF THE REVISED SQUAW CREEK HEC-1 RUNOFF MODEL

Background

There are several rainfall-runoff models and flood prediction packages currently available on the market besides the HEC-1 model. MIKE-11 (Earthsat, 1996b), OMEGA (Correia, 1986) and Floodwatch (Earthsat, 1996a) are examples. However, the widespread use of HEC-1 as a modeling tool for governmental agencies, the desire of local officials for a revised model in a fairly short time frame, and the availability of the researched and calibrated Glanville Squaw Creek HEC-1 model almost precluded the use of any other modeling program for flood warning purposes on the Squaw Creek basin.

Glanville calibrated his model based on a 1975 flooding event. At the time his work was done, the 1975 flood was the flood of record. Since 1987, several additional flooding events have occurred. The June 17, 1990 and July 9, 1993 floods exceeded the discharges of the 1975 flood. It was decided that it would be prudent to recalibrate and reverify the model using the additional available data not only because of the larger flows from the more current storm events, but also because of the addition of a node to the model.

Procedure

The model parameters that were adjusted to calibrate the model are listed earlier in this report and include lag times, routing parameters, baseflow recession constants and curve numbers. During the initial calibration stages for this report, data were only available for peak discharges and time of peak at Lincolnway in Ames for most of the flood events . This information was used to determine the accuracy of the model predictions. It was found that the parameters used by Glanville for his final model still held fairly well with the more current flood events. Minor adjustments were made to the basin lag times lower on the basin to account for the splitting of the E1 and E2 subbasins from Glanville's model. Three high water events for which actual stream hydrographs were available were used to calibrate and verify the basin lag times and routing parameters. Comparisons of the input parameters used in the Glanville model and those used in the calibrated revised model are listed in Tables 10 through 12.

Table 10. Squaw Creek HEC-1 Model Input Comparison - Basin Areas

Subbasin	Glanville Model	Revised Model
A	18.29	17.91
B1	16.78	18.10
B2	22.77	20.66
C1	16.70	15.62
C2	14.42	14.17
D1	24.66	15.88
D2	14.77	14.79
D3	9.46	9.08
D4	17.01	18.72
E1	26.70	6.35
E3		18.59
E2	16.56	10.41
E4		5.20
F	14.27	15.36
G	14.54	16.62
Total	226.93	217.46

Table 11. Squaw Creek HEC-1 Model Input Comparison - Subbasin Lag Times

Subbasin	Glanville Model	Revised Model
A	5.9	6.3
B1	7.9	7.9
B2	4.9	6.8
C1	2.9	5.0
C2	3.1	5.2
D1	9.5	9.5
D2	3.7	5.3
D3	5.0	5.0
D4	2.3	5.7
E1	4.7	1.0
E3		4.7
E2	8.0	4.0
E4		4.0
F	6.3	6.3
G	5.6	5.2

Table 12. Squaw Creek HEC-1 Model Input Comparison - Routing Muskingum k

Routing Reach	Glanville Model	Revised Model
A-B	1.6	1.6
B-C	2.9	2.9
C-D	2.9	2.9
D-E1/E2	3.1	1.5
E1/E2-E3/E4		2.1
E3/E4-F	1.2	2.2
F-G		1.2

To do the calibration and verification, the baseflow was removed from the storm events corresponding to the July 9, 1993, July 17, 1993 and June 24, 1994 floods. Although the June 1990 flood had also occurred fairly recently, the actual stream hydrographs for the 1990 flood were unavailable for comparison purposes as the USGS was in the process of converting from one data system to another and had not transferred hydrograph data from flood events prior to 1991 to the new data system. The actual hydrographs used and baseflows removed are shown in Figures 18 through 20. The USGS hydrograph for the July 9th flood also contained a smaller hydrograph peak from a storm event that had occurred on July 10th. This was removed during the calibration process as the HEC-1 model is designed to model one storm event only. With baseflows removed, the model runoff hydrographs compare almost exactly with the actual runoff hydrographs for the 1993 events. Figures 21 and 22 show the hydrograph comparisons. The modeled time of peak for the 1994 event was not the same as the actual as can be seen in Figure 23. However, the total modeled runoff volumes under both the calibration run and verification runs were within five percent of the actual basin runoff volumes. A graph of model generated runoff volumes versus baseflow-removed actual runoff volumes (Figure 24) and the data tabulated in Table 13 depicts a good correlation between actual and modeled volumes.

In order to model the other storm events, baseflow had to be included in the model. The baseflow recession constant was modified from Glanville's model to better match the recession curves seen in actual hydrographs for the Squaw Creek basin at Lincolnway during a June 1994 recession event where the stream was almost at bank full. The baseflow constant was calculated by averaging several values of Q_a/Q_b where Q_a is an initial flow on the recession portion of the hydrograph curve and Q_b is the flow one hour later. A final value of 1.055 is used in the revised model as compared to 1.02 used in the

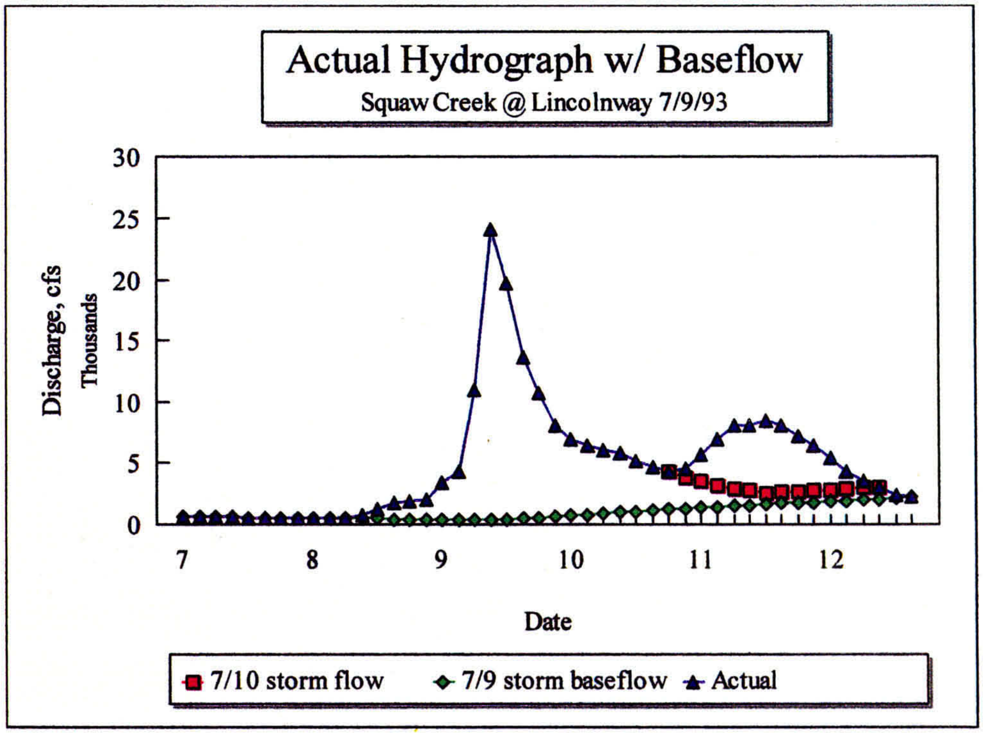

Figure 18. July 9, 1993 Squaw Creek Hydrograph Depicting Baseflows

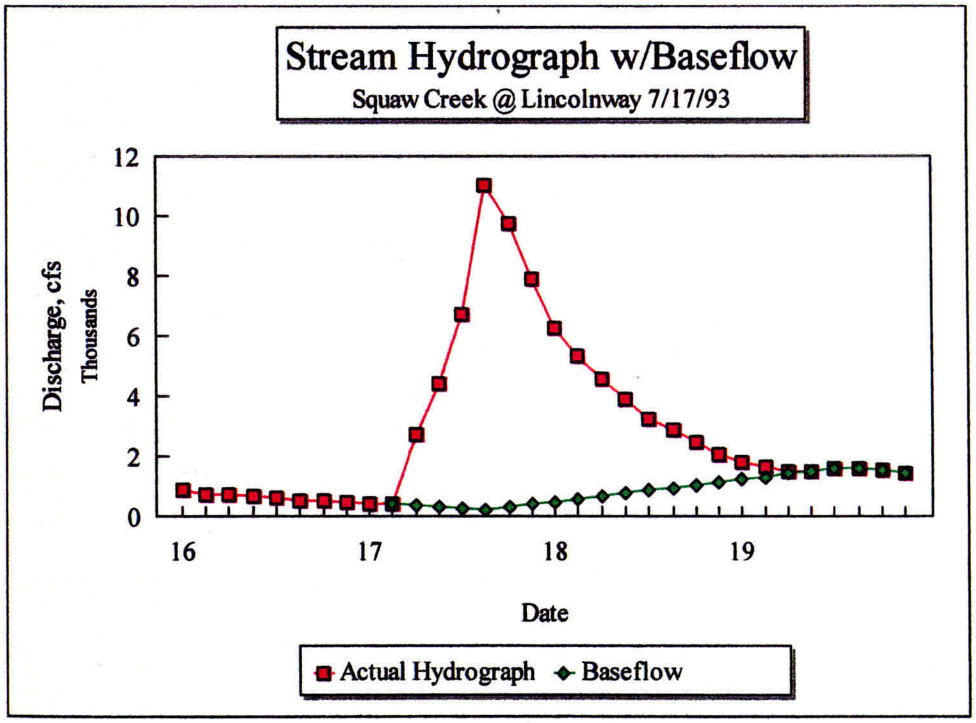

Figure 19. July 17, 1993 Squaw Creek Hydrograph Depicting Baseflow

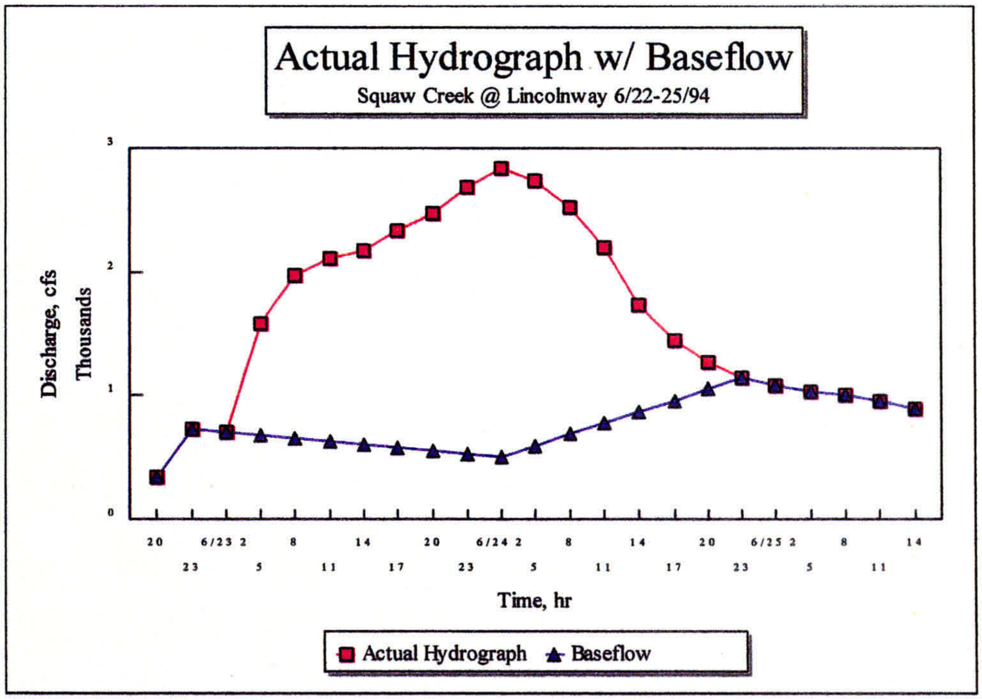

Figure 20. June 24, 1994 Squaw Creek Hydrograph Depicting Baseflow

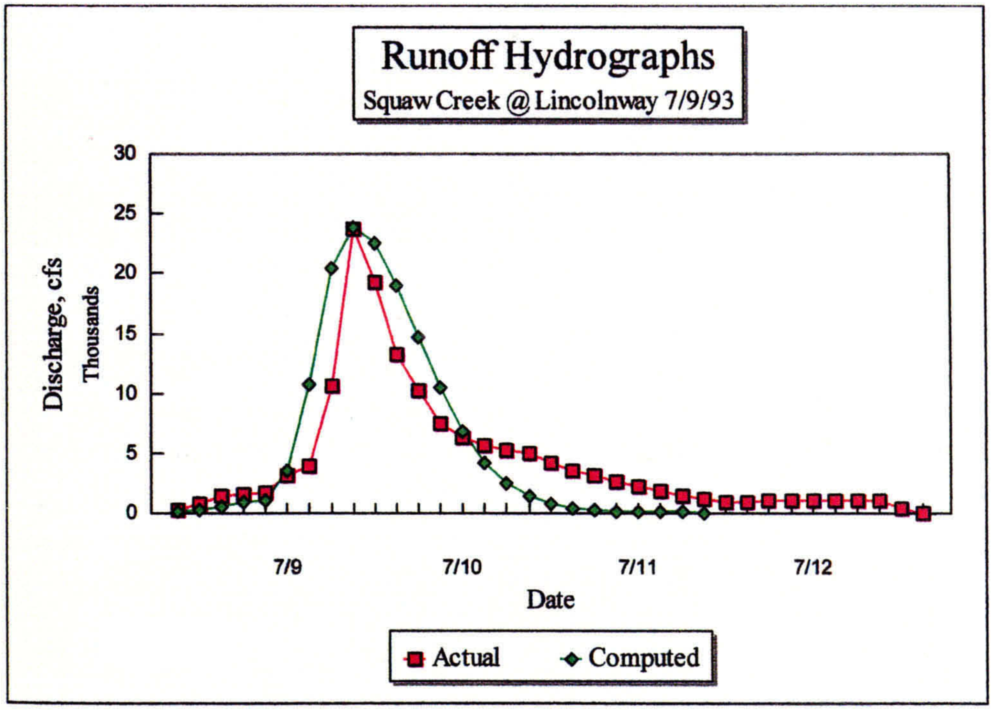

Figure 21. July 9, 1993 Computed and Actual Runoff Hydrographs

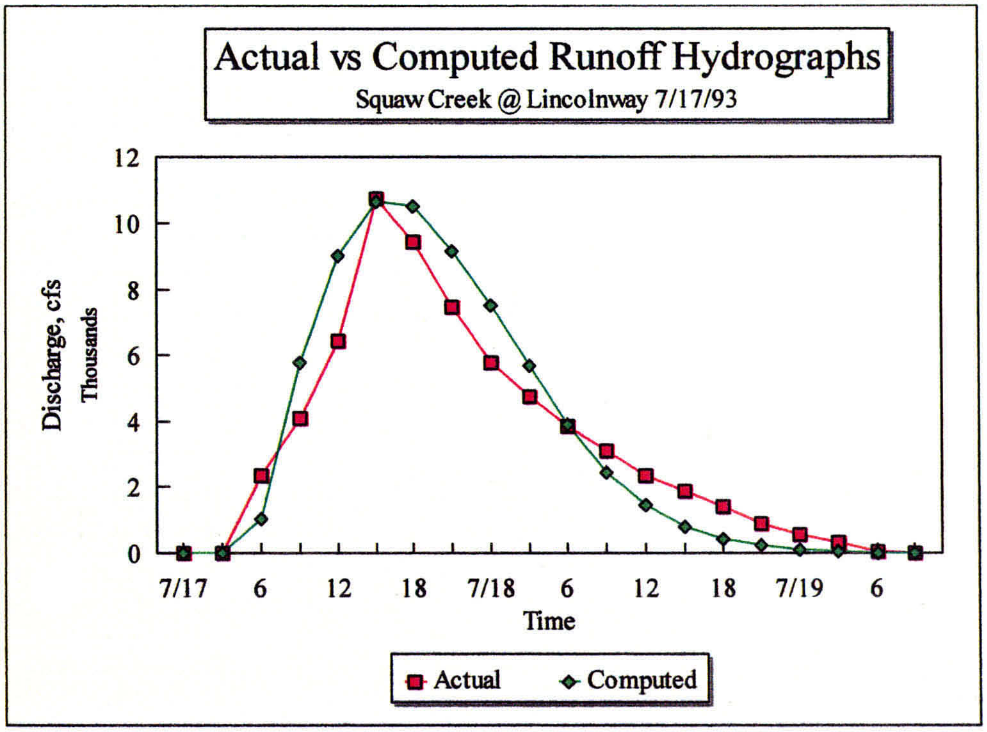

Figure 22. July 17, 1993 Computed and Actual Runoff Hydrographs

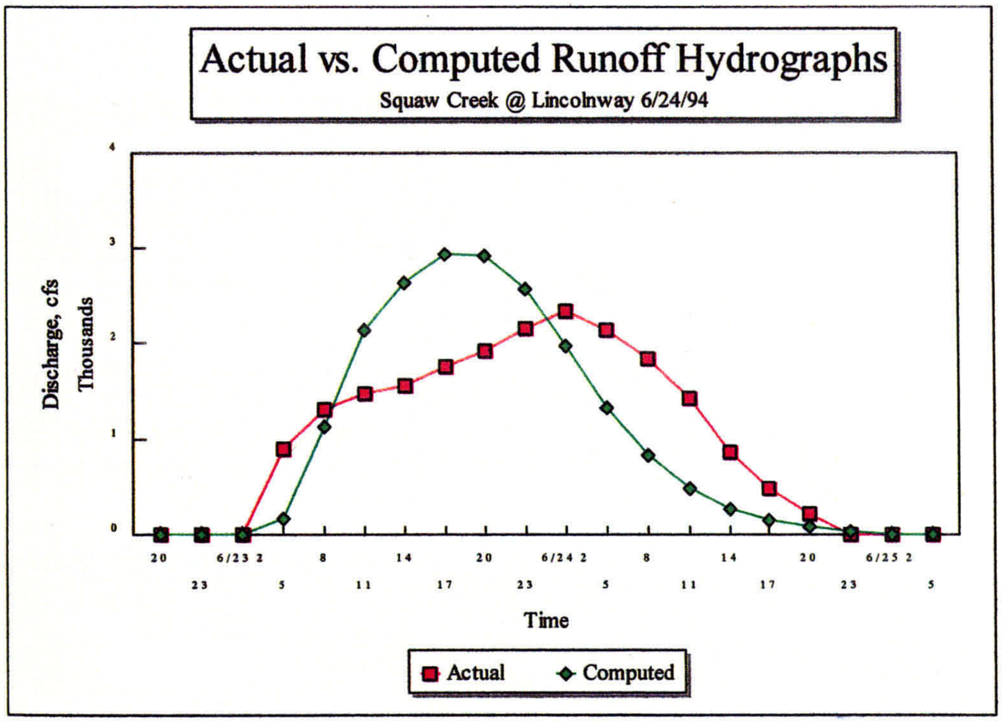

Figure 23. June 24, 1994 Computed and Actual Runoff Hydrographs

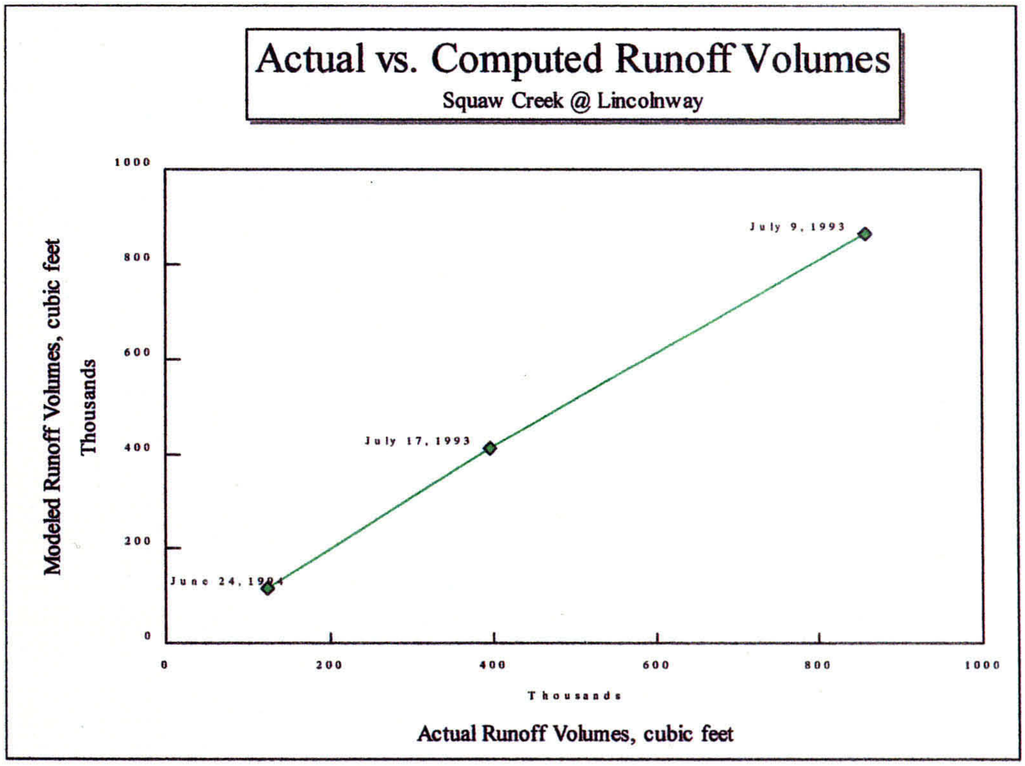

Figure 24. Computed versus Actual Runoff Volumes for Revised Squaw Creek HEC-1 Model

Glanville model. This value was also supported by the recession curve portions of the 1993 hydrographs.

The model came close to predicting the time of peak and peak discharge in almost all cases using the SCS curve numbers associated with an AMC II.5. For the Squaw Creek basin, AMC II.5 is a good starting point for basin SCS curve number input. Table 14 lists the flood events used for verification of the model (baseflow included) with the corresponding actual and predicted times of peak and peak discharges for initial HEC-1 runs without adjustment of the basin curve numbers.

Table 13. Actual and Computed Runoff Volumes

Date of Flood	Actual Runoff cubic feet	Modeled Runoff cubic feet	% Difference
July 9, 1993	857873	864201	0.74
July 17, 1993	396119	412678	4.18
June 24, 1994	123745	118084	4.57

Table 14. Actual vs. Computed Peak Discharges and Times at Lincolnway Initial Runs (No Curve Number Adjustments)

	Actual		Computed		
Date	Peak Flow cfs	Time hr/min	Peak Flow cfs	Time hr/min	AMC
June 27, 1975	11300	0830	5502	0830	III
June 13, 1984	7180	1300 est.	8814	1300	II.5
June 17, 1990	12500	unknown	13566	1030	II.5
July 9, 1993	24300	0830	24634	0830	II.5
July 17, 1993	11090	1545	12180	1600	II.5
June 24, 1994	2841	0215	7124	1600	II.5

The model run for the 1975 flood event did not include the Fibikar Farm precipitation data that Glanville found necessary to use to obtain a better description of precipitation on the basin in the 1975 storm event. Without the additional precipitation data, the modeled peak discharge is considerably lower than the actual. This points to a need for a more comprehensive system of rain gages for the Squaw Creek basin, especially in the northwest corner of the basin.

By adjusting the model curve numbers, it is possible for the model to closely match the actual peak discharges and times. Table 15 lists peak discharges and times of peak for curve number adjusted model runs and the associated curve number adjustments. The value +1, -1, etc. after the AMC numeral indicates what value was added or subtracted from each of the curve numbers to obtain the desired peak discharge. An example of the HEC-1 output for the curve number adjusted Squaw Creek model from the July 17, 1993 storm event is included in Appendix D. The data for COMB2 corresponds to the stream gage at E-18 over Squaw Creek; the data for COMB4 corresponds to the stream gage at Cameron School Road; and the data for COMB6 corresponds to the USGS stream gage at Lincolnway in Ames. It is also possible to adjust the shape of the hydrograph somewhat by adjusting the various curve numbers on the basin to differing degrees. Figures 25 and 26 show how consistent curve number adjustment can affect the peak discharge. Figure 27 portrays the affects of adjusting curve numbers to differing degrees on the basin.

Figures 25 through 27 show that with the baseflow included in both the model and the stream hydrographs, the model and stream hydrographs do not match as well as they did with the runoff-only hydrographs. This can be accounted for by the fact that the hydrographs used for calibration and verification were not just one storm event. Both the July 9 and July 17 flood events had basins reacting to prior or additional storms when the modeled storm occurred. This seems to affect the peak shape more than anything else. The time of peak and peak discharges are still predicted well by the model. Perhaps as more information becomes available from the upper basin stream gages, adjustments will be able to be made to the model to increase the matching of the modeled hydrograph peak shape to the actual.

As shown prior in this document, data were also used for a smaller high water event on June 24, 1994. This event varied from the other calibration and verification storm events in that the basin was not as saturated before the storm event occurred. Using an antecedent rainfall weighting procedure (Chenoweth, 1986), it is easily seen that the antecedent rainfall prior to the 1994 event was much less than that for the 1993 events. Tables 16 and 17 show the weighted antecedent rainfall amounts for the June 1994 and the July 9, 1993 events. The weighted antecedent rainfalls can be used with Figure 28 (Chenoweth, 1986) to adjust the basin curve numbers for antecedent rainfall. This procedure would adjust the June 1994 event curve numbers to an AMC I level and the July 9, 1993 curve numbers to an AMC III level. This closely matches the curve numbers used to obtain modeled hydrographs that match actual hydrographs for those storm events.

As a consequence of the lower antecedent rainfall amounts, neither the computed

Table 15. Actual vs. Predicted Peak Discharges and Times at Lincolnway Curve Numbers Adjusted

	Actual		Predicted		
Date	Peak Flow cfs	Time hr/min	Peak Flow cfs	Time hr/min	AMC
June 13, 1984	7180	1300 est.	7124	1300	II +2
June 17, 1990	12500	unknown	12682	1030	II.5 -2
July 9, 1993	24060	0830	24018	0830	II.5 -1
July 17, 1993	11090	1545	11180	1600	II.5 -2
June 24, 1994	2841	0215	3275	1600	I.5

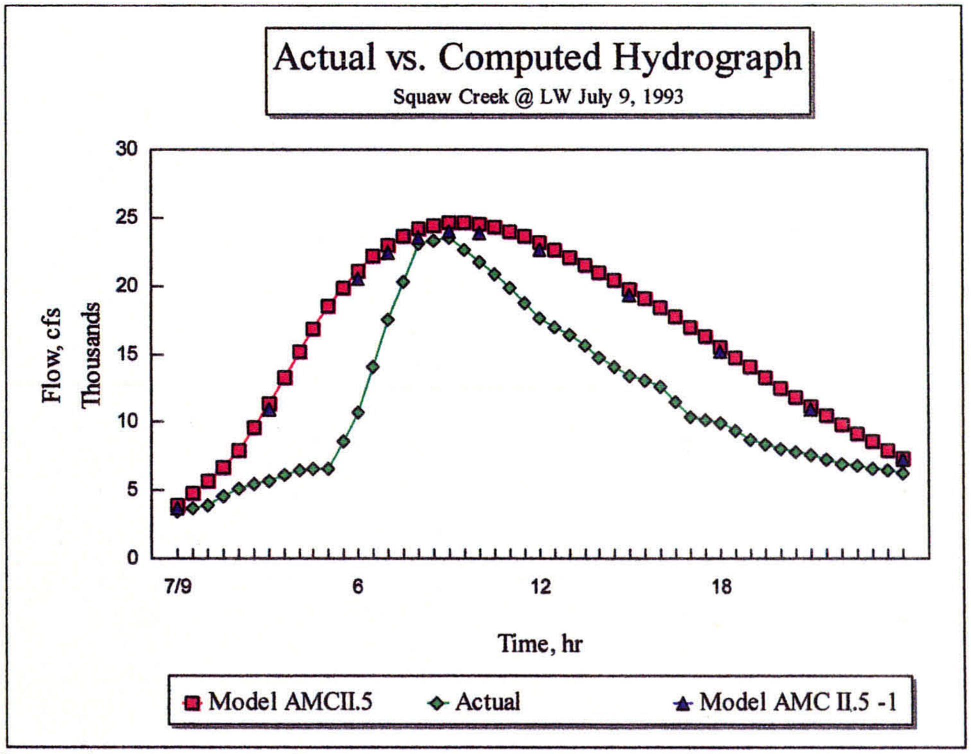

Figure 25. Actual vs. Computed Hydrographs with Baseflow July 9, 1993

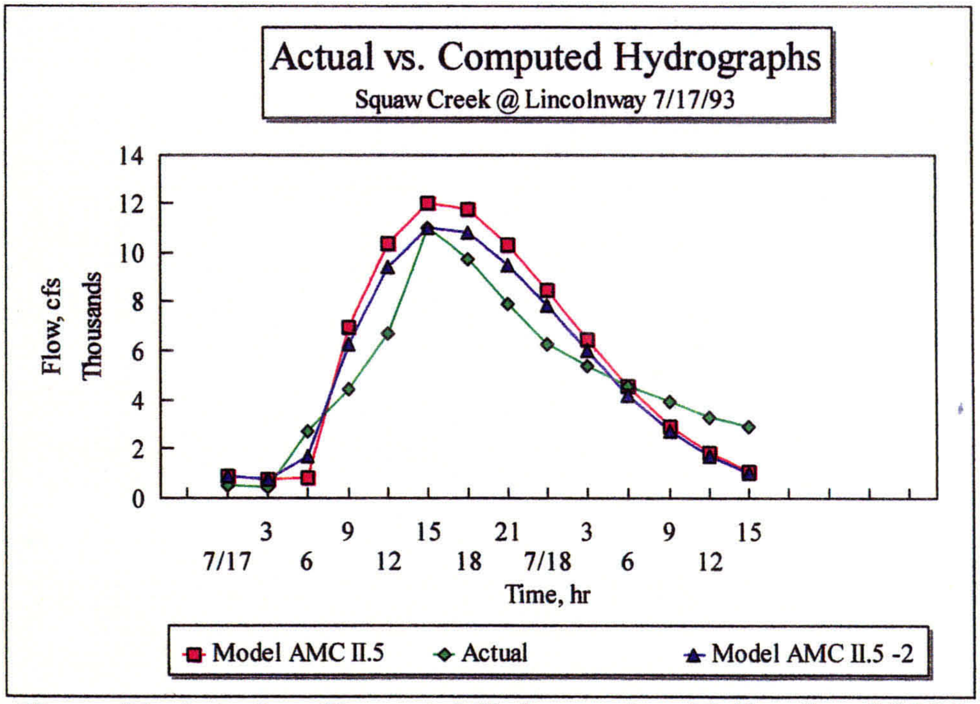

Figure 26. Actual vs. Computed Hydrographs with Baseflow 7/17/93

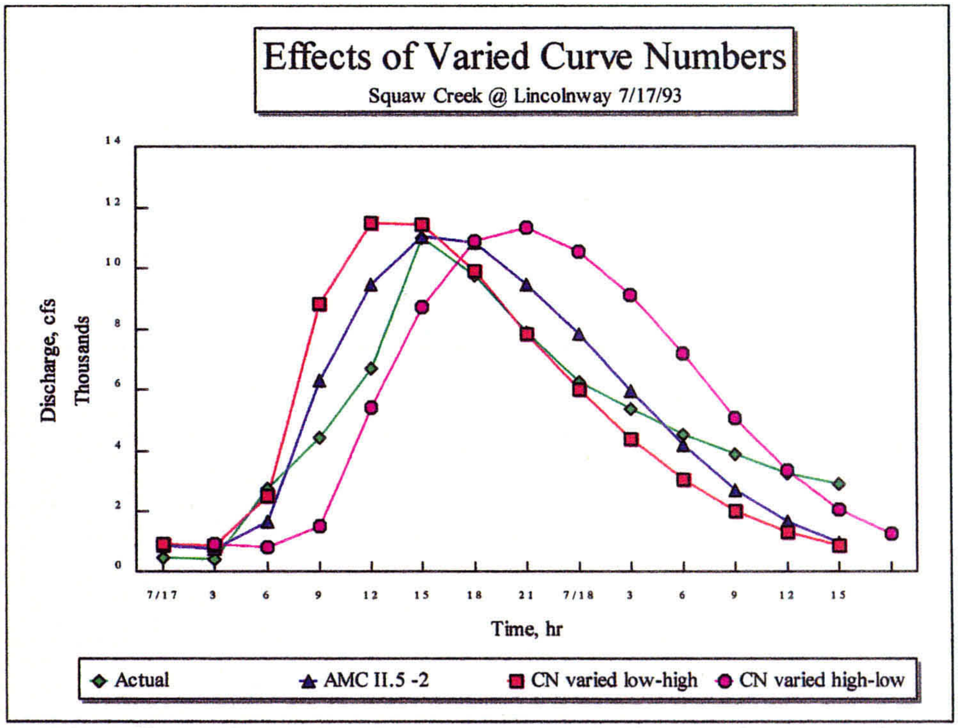

Figure 27. Effects of Varying Curve Numbers in Squaw Creek HEC-1 model

Table 16. Weighted Antecedent Rainfall - June 24, 1994

		Rain gage data, centimeters			
Date	Day	Ames 8WSW	Ogden	Story City	Webster City
June 16	7	0	0	0	0
17	6	1.016	1.016	0	0.762
18	5	0.254	0.254	0	0.254
19	4	0	0	0	0.254
20	3	0.508	0.762	0.254	0.254
21	2	0	0.254	0	0
22	1	0	0	0	0
23		5.334	NA	7.62	7.62
Weighted Antecedent Rainfall, cm		0.874	1.417	0.224	0.739

peak discharge nor the time to peak for the June 1994 high water event matched what actually occurred although the runoff volumes matched very well. Figure 28 shows the actual and computed hydrographs for this event. It is hypothesized that more interflow and infiltration occurred during that event causing the actual peak discharge to be smaller and the time to peak to occur later than the model had predicted. It is also possible that the rainfall was more scattered over the basin than what the available rain gage data weighted according to the Theissen polygon portrayed in the model. This raises a question as to the model's usefulness during relatively normal to dry time periods on the basin.

Table 17. Weighted Antecedent Rainfall - July 9, 1993

		Rain gage data, centimeters			
Date	Day	Ames 8WSW	Ogden	Story City	Webster City
July 2	7	0	0	0.254	0
3	6	0	0	0	0.254
4	5	1.219	0.508	0.762	0
5	4	1.956	2.032	1.524	1.016
6	3	0	0	0	0
7	2	0.381	0.508	0.254	0
8	1	1.803	15.24	9.144	6.096
9		11.811	1.016	3.302	2.54
Weighted Antecedent Rainfall, cm		5.475	29.555	18.113	11.681

Cameron School Road Correlations

A comparison was also made between the model output and the actual peak discharge at Cameron School Road based on the developed stage-discharge curves and the surveyed high water marks for the July 9 and 17, 1993 flood events. The peak discharge for July 9th as determined from the computed stage-discharge curves for the surveyed high water marks was 22600 cfs. The model gave a discharge of 20989 cfs at Cameron School Road when the model and actual flows were matching at Lincolnway. This is a reasonably good match.

For July 17th, the peak discharge from the computed stage-discharge curves for Cameron School Road was approximately 13000 cfs. This value seems high considering the peak discharge at Lincolnway was 11090 cfs. The model produced a discharge of 10456 cfs for Cameron School Road which corresponds more closely with the actual peak discharge at Lincolnway. It appears from the limited data available that the model's peak discharges at Cameron School Road are reasonably closely matching the actual basin response. Once the stream gages at Cameron School Road and E-18 over Squaw Creek are calibrated, it will be of interest to do more accurate comparisons.

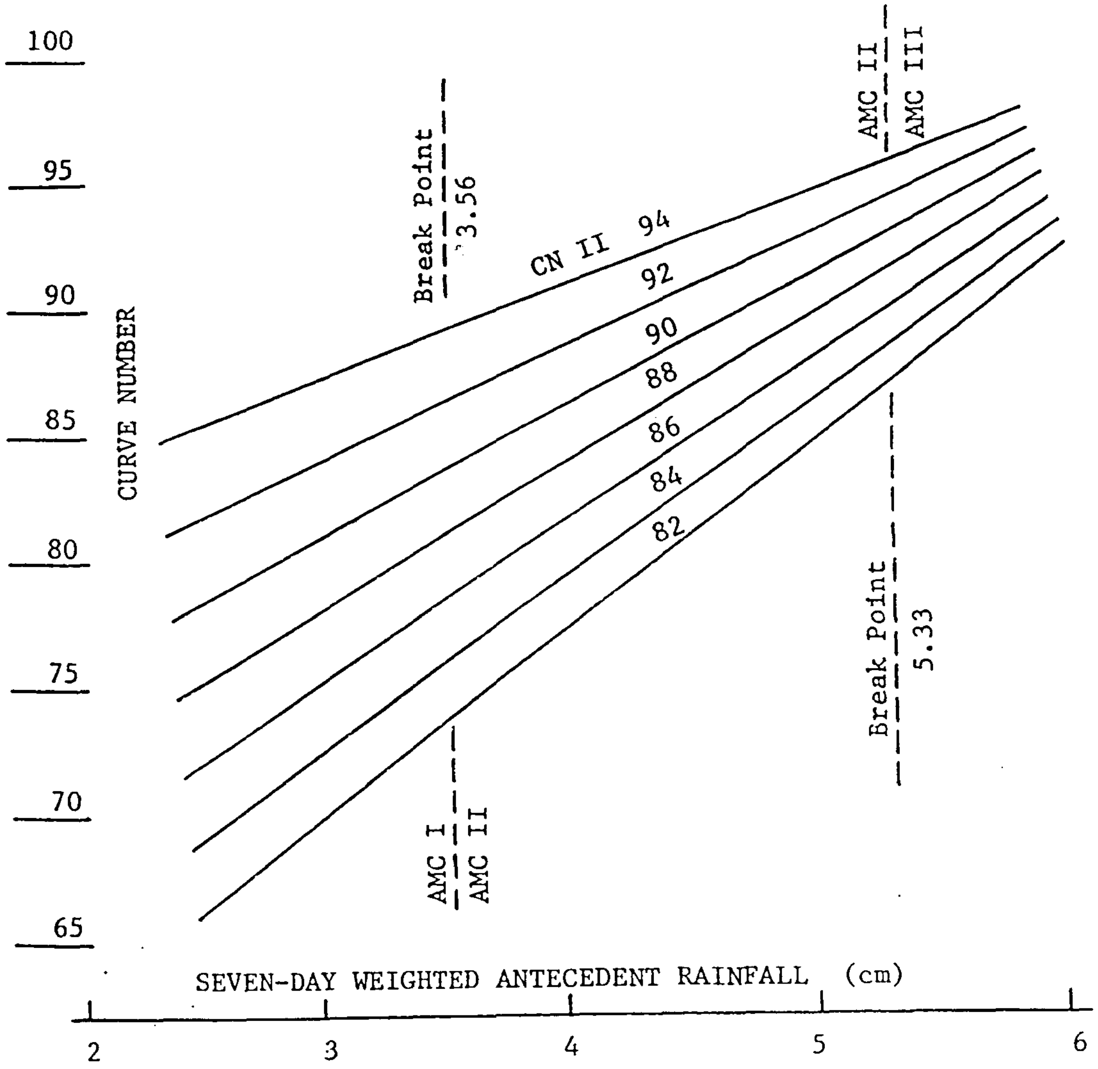

Figure 28. Sliding Scale Runoff Curve Number (Chenoweth, 1986, p.21)

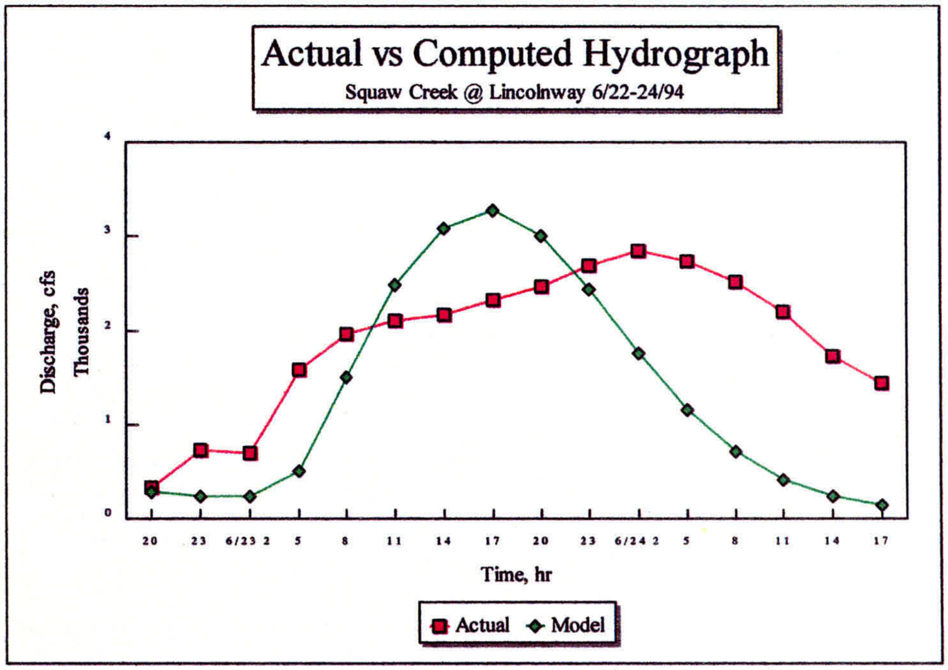

Figure 29. Actual vs. Computed Hydrographs for Squaw Creek 6/22-24/94

The only high water situation for which gaged timing data were available for both the Lincolnway and Cameron School Road stream gages was that of June 24, 1994. Unfortunately, this is the verification run where the timing parameters are in question. Both the predicted peak at Lincolnway and the predicted peak at Cameron School Road were earlier by about 8 hours than the actual records for those locations indicate. Adjusting curve numbers can reduce this difference by several hours. However, if the model is to be used for lesser high water events occurring under drier antecedent moisture conditions, the model lag times and routing parameters may have to be adjusted to better match what is actually occurring on the basin.

The theory that basin timing parameters are different during saturated versus dry conditions is also supported by the observation that the difference in time to peak between Cameron School Road and Lincolnway was higher under dry conditions than under saturated conditions. During the 1993 floods, the difference between times to peak was two to three hours as observed by water plant personnel. The timing difference for the 1994 event was six hours.

NEEDS FOR REAL-TIME MODEL USE
POSSIBILITIES FOR FURTHER STUDY

Needs for Real-time Model Use

Need for Real-time Precipitation Data

As had been mentioned earlier, there currently are no means to obtain real-time precipitation data for the Squaw Creek basin. Hourly precipitation data used in model calibration and verification were at least eight months old at the time of use. Real-time daily precipitation is available, but that is not on a frequent enough time scale to be useful in predicting flooding on a basin that responds within twenty-four hours to a storm event. There is a need for real-time hourly precipitation data in a format readily entered into the model.

Some options that could be explored in regard to real-time precipitation data are: placing rain gages on the basin which would be monitored along with the stream gages at the City of Ames Water Plant, using a commercial electronic meteorological service to supply statistically analyzed precipitation data for the basin, or finding a means to work cooperatively with the National Weather Service and the National Climatic Data Center to obtain hourly precipitation data from the radar data used in weather forecasting (NEXRAD). There are costs and benefits associated with each of these options.

Placing rain gages on the basin is costly in both the initial expenditure for equipment and in the costs of operation and maintenance on a long-term basis. The initial cost of putting ten rain gages on the Squaw and Skunk River basins is $1901 per gage. The costs for telephone and/or electric service to the rain gage sites runs approximately $50 per month. There would also be a cost for personnel to maintain and monitor the gages. No estimate has been prepared as it is unknown who the personnel would be.

Commercial electronic meteorological services are also available. These services offer the ability to download statistically analyzed weather information by e-mail or have it sent via fax to the location of use. They use radar data from the National Weather Service which is then run through a computer algorithm to allocate the precipitation over the basin. The concern here is the accuracy of the information input into their computer algorithms and the effects the algorithms have on the allocation over the basin. With many of the services, the data are only downloaded once per day at a specific time each day for the preceding twenty-four hours. This could be a problem if the storm event were to begin just after the day's data had been downloaded. The flood would most likely occur prior to the receiving of the data to predict it. There is a monthly charge associated with these services which varies depending on the size of the basin, data requested and the supplier chosen. The lowest charge seen was $50 per month per site.

There is also a possibility that in the near future Iowa State University will have access to the NEXRAD system used by the National Weather Service for weather forecasting. This system uses enhanced radar images to determine the amount of precipitation over a given area. Some of the same concerns that were discussed for the commercial providers apply to the NEXRAD system as far as how the computer algorithms determine the amount of precipitation. The question as to how the data from the radar images would be translated into a format that can be used in the model may be answered by the successor to the HEC-1 program currently being developed at the Hydrologic Engineering Center in Davis, California (Feldman, 1996). The new model makes use of three programs, ModClark, GridParm-DEM2HRAP, and HEC-DSS. ModClark is a Modified Clark Runoff Simulation model that incorporates National Weather Service WSR-88D radar data into a runoff simulation model. GridParm-DEM2HRAP creates a basin parameter grid from USGS Digital Elevation Models topographic information. HEC-DSS is a data storage system to which the created hydrographs are written. Previous HEC-1 models can input the hydrographs from the HEC-DSS files. The successor program to HEC-1, HEC-HMS will make use of these subprograms in a PC-based Windows environment. It is expected to be beta tested late in 1996. It is still uncertain though when the university will begin to have access to the NEXRAD data and how much information will be available at that time.

Need for Real-time Feedback Loops for Model Modification

Once real-time precipitation data are available to input into the model, there needs to be a means to continually update the model to better match the data being supplied from the upstream stream gages. It is the assumption that a series of feedback loops would be needed that would adjust curve numbers and possibly basin lag times to help the upstream modeled hydrographs match the hydrographs coming off of the upstream stream gages. A possible schematic for such a procedure is shown in Figure 30. It is hoped that if the modeled stream gage readings match the actual upstream, then the prediction of the degree of flooding to occur in Ames will be accurate enough and early enough that officials in Ames will have adequate time to sandbag and/or evacuate residents if necessary prior to the occurrence of the flood. Hopefully the amount of lead

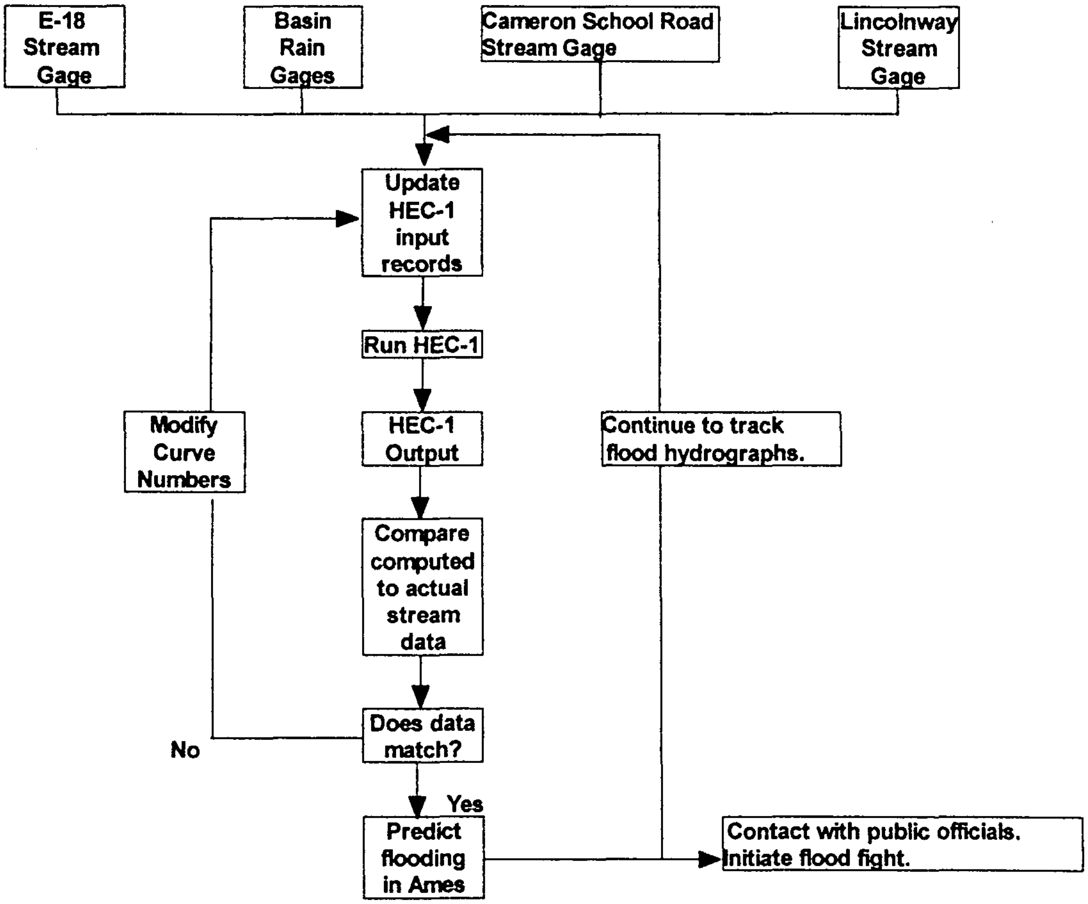

Figure 30. Schematic of a Real-time Modeling Feedback Loop

time for city officials will be increased from the "drive upstream and look" method by two to three hours.

Persons using this model on a real-time basis will need a user-friendly manual to guide them through the use of the model. The initial users of the model in a storm event may be water plant operators or water plant technical staff. Without a complete step-by-step guide to the use of the model, those persons may not feel comfortable using the model. This could delay flood prediction and negate some of the benefits of the computer modeling process. Once the real-time model is completed and ready for use, a complete user manual will need to be developed. Training of the persons who may need to use the model would also be advisable.

Possibilities for Further Study

Modifications of the Model to Include New City of Ames Rain Gages

At the writing of this thesis, ten rain gages have been ordered by the City of Ames to be placed on the Squaw Creek and Skunk River basins. After the gages are installed, a new Theissen polygon will need to be created, and the model will need to be revised again to include the new rain gage locations. Calibration and verification of the newly revised model will also be necessary.

Locations for the new rain gages were proposed to the City as part of this project. The proposed rain gage locations and the corresponding Theissen polygon are depicted in Figure 31. The proposed locations attempted to place the new rain gages on public or cooperative properties to minimize difficulties in obtaining access for maintenance of the rain gages.

Inclusion of the Squaw Creek Model in the Skunk River Model

The Squaw Creek basin model is only part of the larger flood warning system envisioned for the Ames community. Another model is being developed for the Skunk River that may include the Squaw Creek model as one of its subbasins. If that happens, it may be necessary to adjust the Squaw Creek model to accommodate its use by the larger model and flood warning system.

Comparisons of Model Output to Actual High Water Events Upstream of Ames

At the writing of this thesis, few calibrated data were available from the stream gages at Cameron School Road and E-18 over Squaw Creek. The stream gages were installed in 1994, but were not calibrated until after the high water event in June 1994. Since that time there have been no storm events that have caused a concern of flooding on the basin.

When such data become available, it will be necessary to adjust the basin lag times, routing parameters and possibly also the SCS curve numbers associated with the upper

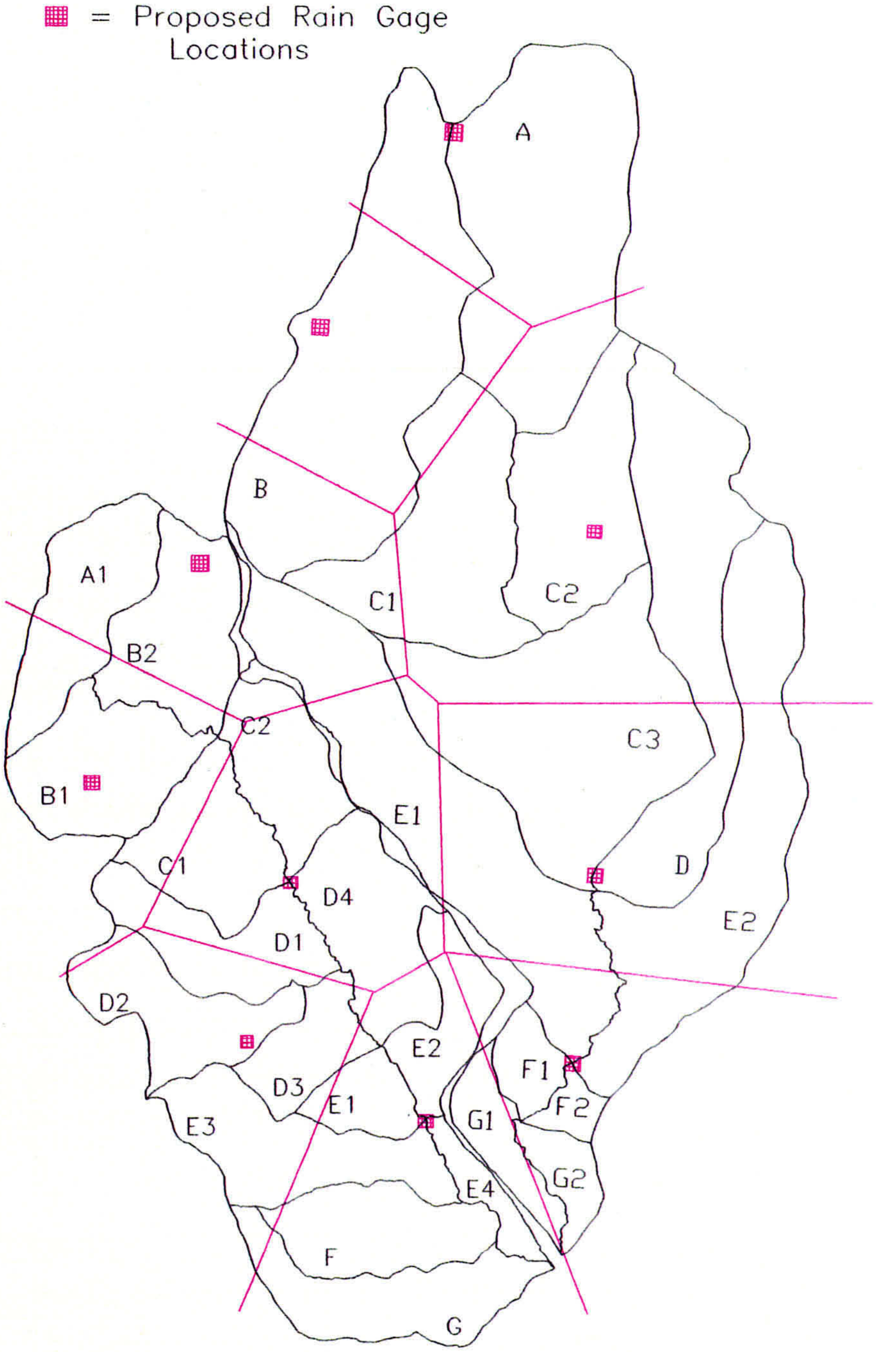

Figure 31. Proposed Locations of New Rain Gages and Corresponding Theissen Polygon

subbasins to match the actual times of peak and discharges seen at the stream gages. This will lead to the need to once again recalibrate and verify the model.

CONCLUSION

The HEC-1 flood modeling program developed by Glanville for the Squaw Creek basin has been modified to include a node at the location of Cameron School Road. Following the modification, the model was calibrated and verified. The parameters Glanville developed for the Squaw Creek basin needed little adjustment even with the creation of the new nodes. The model correlates fairly well during large flood events, but may not be as accurate for high water events on a non-saturated basin.

The model can be used to predict flooding in real-time, but the precipitation data will need to be upgraded so that it is available on at least an hourly basis to obtain an accurate prediction. In the best possible situation, the amount of time local officials will have to react to the flooding event will be eight to nine hours.

This model should be used only as part of a comprehensive floodplain management plan. Flood prediction can only help people react to an event that is already occurring. Planning for future events by adjusting planning and zoning requirements in the floodplain could eliminate many of the damage centers and the need for flood prediction. While complete removal of all development in the floodplain is probably not feasible, local officials should explore the means of limiting and/or reducing development in these areas in the future.

APPENDIX A. STREAM CROSS-SECTION DATA

Table A1. Stream Valley Cross-sections for E18 Bridge over Skunk River

Cross-section A			Cross-section B		
Station	Elevation	n	Station	Elevation	n
0	48.0	0.100	0	57.6	0.100
23	47.7	0.100	37	56.6	0.100
38	50.7	0.100	59	44.2	0.035
66	51.1	0.100	82	42.7	0.035
74	48.2	0.100	103	43.1	0.100
79	44.2	0.035	123	48.5	0.100
88	43.6	0.035	158	54.5	0.100
103	43.8	0.035	187	54.3	0.100
106	43.2	0.035	202	56.7	0.100
118	42.8	0.035	254	56.6	0.100
132	43.3	0.035			
139	44.2	0.100			
147	45.6	0.100			
154	48.5	0.100			
170	58.8	0.100			
176	60.4	0.100			
187	60.4	0.100			
199	60.1	0.100			
238	59.7	0.100			
251	58.2	0.100			
262	56.7	0.100			

Drainage Area = 230 square miles

Stream slope = 5.106 feet/mile

Table A2. Stream Valley Cross-sections for E18 Bridge over Squaw Creek

Cross-section A			Cross-section B		
Station	Elevation	n	Station	Elevation	n
0	971.0	0.100	0	1010.9	0.100
66	967.5	0.100	95	1011.0	0.100
170	969.0	0.100	195	969.6	0.100
260	968.0	0.100	300	967.5	0.100
286	967.7	0.035	400	968.0	0.035
315	962.5	0.035	420	960.6	0.035
340	969.3	0.100	445	968.0	0.037
420	972.6	0.100	592	966.2	0.037
475	972.4	0.037	692	968.8	0.037
577	970.3	0.037	795	969.2	0.037
677	970.0	0.037	895	970.0	0.037
777	969.9	0.037			

Drainage area = 90 square miles   Stream slope = 4.94 feet/mile

Table A3. Stream Valley Cross-sections for Cameron School Road Bridge

Cross-section A			Cross-section B		
Station	Elevation	n	Station	Elevation	n
0	922.5	0.100	0	940.0	0.100
93	905.0	0.100	170	912.0	0.100
156	905.4	0.035	280	912.0	0.100
200	911.7	0.037	390	913.5	0.100
282	911.1	0.037	400	905.1	0.035
450	914.7	0.037	440	905.1	0.035
500	913.0	0.037	450	911.3	0.100
600	912.6	0.032	590	912.6	0.032
700	913.5	0.032	700	912.4	0.032
800	915.6	0.032	810	912.3	0.032
900	917.6	0.032	920	912.5	0.032
1000	920.3	0.032	1030	914.0	0.032
1100	925.8	0.032	1140	915.4	0.032
			1250	917.8	0.032
			1360	919.5	0.032

Drainage area = 170 square miles   Stream slope = 5.28 feet/mile

Table A4. Surveyed Streambed Cross-section for Peterson Pits bridge

Station	Elevation	n
0	102.58	0.050
25	101.60	0.050
50	100.74	0.050
75	99.91	0.050
109	84.4	0.035
120	80.8	0.035
130	80.4	0.035
140	80.0	0.035
150	78.7	0.035
160	78.5	0.035
170	78.6	0.035
180	78.0	0.035
190	79.2	0.035
200	81.4	0.035
208	84.4	0.035
217	97.39	0.050
312	94.8	0.050
317	92.6	0.050
332	91.0	0.032
417	90.9	0.032
517	91.9	0.032
617	93.1	0.100

Drainage area = ~310 square miles

Stream slope = 2.508 feet/mile (surveyed)
Stream slope = 5.388 feet/mile (topographic map)

Table A5. Surveyed Streambed Cross-section for E18 over Squaw Creek

Section	Elevation	n
0	982.3	0.100
2	982.2	0.100
2	980.1	0.100
12	978.5	0.100
22	976.2	0.100
32	975.5	0.100
37	974.0	0.100
37	968.2	0.035
42	967.4	0.035
52	967.2	0.035
62	965.3	0.035
84	963.4	0.035
92	963.0	0.035
102	959.2	0.035
112	960.1	0.035
122	960.7	0.035
130	960.6	0.035
130	973.7	0.100
132	973.7	0.100
142	974.5	0.100
150	974.6	0.100
152	976.6	0.100

Table A6. Surveyed Streambed Cross-section for Cameron School Road

Section	Elevation	n
0	921.1	0.075
10	917.7	0.075
20	914.0	0.075
30	908.6	0.075
40	906.0	0.075
50	904.7	0.035
60	901.7	0.035
70	903.7	0.035
80	903.6	0.035
83	903.7	0.035
90	903.9	0.035
100	903.9	0.035
110	904.4	0.035
120	904.2	0.035
130	907.2	0.035
140	907.5	0.035
150	908.8	0.035
160	909.9	0.035
170	913.5	0.075
180	916.4	0.075
190	919.7	0.075
199	921.9	0.075

Table A7. Surveyed Streambed Cross-section + Road Elevations from Bridge Plans for Cameron School Road

Section	Elevation	n
0	925.6	0.075
100	924.2	0.075
200	923.1	0.075
300	922.5	0.075
400	922.8	0.075
500	923.3	0.075
600	924.1	0.075
700	921.1	0.075
710	917.7	0.075
720	914.0	0.075
730	908.6	0.075
740	906.0	0.075
750	904.7	0.035
760	901.7	0.035
770	903.7	0.035
780	903.6	0.035
790	903.9	0.035
800	903.9	0.035
810	904.4	0.035
820	904.2	0.035
830	907.2	0.035
840	907.5	0.035
850	908.8	0.035
860	909.9	0.035
870	913.5	0.075
880	916.4	0.075
890	919.7	0.075
898	921.9	0.075
900	922.5	0.075
1000	928.0	0.075

APPENDIX B. STAGE-DISCHARGE CURVE TABLES

Table B1. Peterson Pits Bridge PCVAL output

Surveyed Slope = 2.508 ft/mile		Map Slope = 5.388 ft/mile	
Elevation ft	Discharge cfs	Elevation ft	Discharge cfs
79	12	79	17
80	72	80	106
81	179	81	263
82	374	82	548
83	630	83	923
84	943	84	1382
85	1334	85	1955
86	1795	86	2631
87	2311	87	3387
88	2879	88	4219
89	3497	89	5126
90	4166	90	6106
91	4883	91	7158
92	5777	92	8468
93	6965	93	10209

Table B2. Cameron School Road Bridge PCVAL Output for Map Cross-sections

Cross-section A		Cross-section B	
Elevation ft	Discharge cfs	Elevation ft	Discharge cfs
905.5	11	905.5	12
906.5	137	906.5	95
907.5	368	907.5	235
908.5	697	908.5	422
909.5	1124	909.5	653
910.5	1650	910.5	925
911.5	2144	911.5	1223
912.5	3033	912.5	1624
913.5	4230	913.5	2925
914.5	6255	914.5	5193
915.5	9223	915.5	8330
916.5	12983	916.5	12449
917.5	17489	917.5	17399
918.5	22811	918.5	23026
919.5	28884	919.0	26125
920.0	32201		

Table B3. Cameron School Road PCVAL Output for Surveyed Cross-sections

Surveyed + Road Elev.		Surveyed + Road Elev.		Surveyed only	
n = 0.075/0.035		n = 0.100/0.035		n = 0.075/0.035	
Elevation ft	Discharge cfs	Elevation ft	Discharge cfs	Elevation ft	Discharge cfs
902.5	2	902.5	2	902.5	2
903.5	17	903.5	17	903.5	13
904.5	69	904.5	69	904.5	60
905.5	257	905.5	256	905.5	226
906.5	539	906.5	537	906.5	482
907.5	855	907.5	850	907.5	771
908.5	1308	908.5	1296	908.5	1190
909.5	1851	909.5	1830	909.5	1754
910.5	2534	910.5	2503	910.5	2438
911.5	3346	911.5	3300	911.5	3216
912.5	4253	912.5	4192	912.5	4085
913.5	5255	913.5	5175	913.5	5043
914.5	6429	914.5	6329	914.5	6083
915.5	7701	915.5	7578	915.5	7205
916.5	9073	916.5	8922	916.5	8415
917.5	10543	917.5	10360	917.5	9713
918.5	12110	918.5	11890	918.5	11094
919.5	13775	919.5	13512	919.5	12561
920.5	15537	920.5	15226	920.5	14109
921.5	17243	921.5	16915	921.0	14915
922.5	18995	922.5	18658		
923.5	20500	923.5	20231		
924.5	23186	924.5	22708		
925.5	26466	925.5	25647		

Table B4. E-18 over Squaw Creek Bridge PCVAL Output

Map Cross-section A		Map Cross-section B		Surveyed Cross-section	
Elevation ft	Discharge cfs	Elevation ft	Discharge cfs	Elevation ft	Discharge cfs
				960.0	3
		961.0	0	961.0	30
		962.0	6	962.0	109
963.0	1	963.0	25	963.0	224
964.0	11	964.0	63	964.0	345
965.0	43	965.0	125	965.0	535
966.0	105	966.0	216	966.0	809
967.0	206	967.0	365	967.0	1149
968.0	360	968.0	728	968.0	1484
969.0	635	969.0	1514	969.0	2012
				970.0	2608
				971.0	3254
				972.0	3946
				973.0	4680
				974.0	5463
				975.0	6352
				975.7	7045

Table B5. E-18 over Skunk River Bridge PCVAL Output

Map Cross-section A		Map Cross-section B	
Elevation ft	Discharge cfs	Elevation ft	Discharge cfs
43	0	43	1
44	33	44	44
45	168	45	160
46	385	46	336
47	673	47	564
48	1022	48	841
		49	1165
		50	1536
		51	1954
		52	2421
		53	2937
		54	3503
		55	4047
		56	4757

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
05470500 DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
SQUAW CREEK AT AMES, IA DD: 3 TYPE: 001 RATING NO: 08
OFFSET: 1.00 START DATE/TIME: 10-01-92 (0015)
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	.05	(EXPANDED PRECISION) .06	.07	.08	.09	DIFF IN Q PER TENTH FT
1.30	2.900	3.182	3.482	3.799	4.135	4.489	4.862	5.255	5.667	6.101	3.654
1.40	6.554	7.030	7.527	8.046	8.587	9.152	9.740	10.35	10.99	11.65	5.786
1.50	12.34	13.05	13.79	14.55	15.34	16.16	17.01	17.89	18.79	19.72	8.350
1.60	20.69	21.68	22.70	23.75	24.84	25.95	27.10	28.28	29.49	30.74	11.33
1.70	32.02	33.33	34.68	36.06	37.48	38.94	40.43	41.95	43.51	45.11	14.73
1.80	46.75	48.43	50.14	51.89	53.69	55.52	57.39	59.30	61.25	63.25	18.53
1.90	65.28	67.36	69.48	71.64	73.84	76.09	78.38	80.72	83.10	85.53	22.72
2.00	88.00	90.30	92.65	95.02	97.44	99.89	102.4	104.9	107.5	110.1	24.70
2.10	112.7	115.4	118.1	120.9	123.7	126.5	129.4	132.3	135.3	138.3	28.60
2.20	141.3	144.4	147.5	150.7	153.9	157.1	160.4	163.8	167.1	170.5	32.70
2.30	174.0	177.3	180.6	184.0	187.4	190.8	194.3	197.8	201.4	205.0	34.60
2.40	208.6	212.2	215.9	219.7	223.5	227.3	231.1	235.0	238.9	242.9	38.30
2.50	246.9	251.0	255.1	259.2	263.3	267.5	271.8	276.1	280.4	284.7	42.20
2.60	289.1	293.6	298.1	302.6	307.1	311.7	316.4	321.1	325.8	330.6	46.30
2.70	335.4	340.2	345.1	350.0	355.0	360.0	364.2	368.4	372.7	376.9	45.80
2.80	381.2	385.5	389.9	394.2	398.6	403.0	407.5	412.0	416.4	421.0	44.30
2.90	425.5	430.1	434.7	439.3	443.9	448.6	453.3	458.0	462.7	467.5	46.80
3.00	472.3	477.1	481.9	486.8	491.7	496.6	501.5	506.5	511.4	516.5	49.20
3.10	521.5	526.6	531.6	536.7	541.9	547.0	552.2	557.4	562.7	567.9	51.70
3.20	573.2	578.5	583.8	589.2	594.6	600.0	604.8	609.6	614.4	619.3	50.90
3.30	624.1	629.0	633.9	638.8	643.7	648.7	653.6	658.6	663.6	668.6	49.50
3.40	673.6	678.7	683.8	688.8	693.9	699.0	704.2	709.3	714.5	719.6	51.20
3.50	724.8	730.0	735.3	740.5	745.8	751.0	756.3	761.6	767.0	772.3	52.90
3.60	777.7	783.0	788.4	793.8	799.3	804.7	810.2	815.6	821.1	826.6	54.40
3.70	832.1	837.7	843.2	848.8	854.4	860.0	864.6	869.3	874.0	878.6	51.20
3.80	883.3	888.0	892.7	897.4	902.1	906.8	911.5	916.3	921.0	925.8	47.20
3.90	930.5	935.3	940.0	944.8	949.6	954.4	959.2	964.0	968.9	973.7	48.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
DD: 3 TYPE: 001 RATING NO: 08
START DATE/TIME: 10-01-92 (0015)

05470500
SQUAW CREEK AT AMES, IA
OFFSET: 1.00
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND						(EXPANDED PRECISION)				DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
4.00	978.5	983.4	988.2	993.1	997.9	1003	1008	1013	1017	1022	48.50
4.10	1027	1032	1037	1042	1047	1052	1057	1062	1067	1072	50.00
4.20	1077	1082	1087	1092	1097	1102	1107	1112	1117	1122	50.00
4.30	1127	1132	1137	1142	1147	1153	1158	1163	1168	1173	51.00
4.40	1178	1183	1189	1194	1199	1204	1209	1214	1220	1225	52.00
4.50	1230	1234	1239	1243	1247	1251	1256	1260	1264	1269	43.00
4.60	1273	1277	1282	1286	1290	1294	1299	1303	1307	1312	43.00
4.70	1316	1320	1325	1329	1333	1338	1342	1346	1351	1355	43.00
4.80	1359	1364	1368	1373	1377	1381	1386	1390	1394	1399	44.00
4.90	1403	1407	1412	1416	1421	1425	1429	1434	1438	1443	44.00
5.00	1447	1451	1456	1460	1465	1469	1473	1478	1482	1487	44.00
5.10	1491	1496	1500	1504	1509	1513	1518	1522	1527	1531	45.00
5.20	1536	1540	1544	1549	1553	1558	1562	1567	2571	1576	44.00
5.30	1580	1585	1589	1594	1598	1603	1607	1611	1616	1620	45.00
5.40	1625	1629	1634	1638	1643	1647	1652	1656	1661	1665	45.00
5.50	1670	1674	1678	1681	1685	1689	1693	1697	1700	1704	38.00
5.60	1708	1712	1715	1719	1723	1727	1731	1734	1738	1742	38.00
5.70	1746	1750	1753	1757	1761	1765	1769	1772	1776	1780	38.00
5.80	1784	1788	1791	1795	1799	1803	1806	1810	1814	1818	38.00
5.90	1822	1825	1829	1833	1837	1841	1844	1848	1852	1856	38.00
6.00	1860	1863	1867	1871	1875	1879	1882	1886	1890	1894	38.00
6.10	1898	1901	1905	1909	1913	1917	1920	1924	1928	1932	38.00
6.20	1936	1939	1943	1947	1951	1955	1958	1962	1966	1970	38.00
6.30	1974	1977	1981	1985	1989	1993	1996	2000	2004	2008	38.00
6.40	2012	2015	2019	2023	2027	2031	2034	2038	2042	2046	38.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
DD: 3 TYPE: 001 RATING NO: 08
START DATE/TIME: 10-01-92 (0015)

05470500
SQUAW CREEK AT AMES, IA
OFFSET: 1.00
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)					DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
6.50	2050	2053	2057	2061	2065	2069	2072	2076	2080	2084	38.00
6.60	2088	2091	2095	2099	2103	2107	2111	2114	2118	2122	38.00
6.70	2126	2130	2133	2137	2141	2145	2149	2152	2156	2160	38.00
6.80	2164	2168	2171	2175	2179	2183	2187	2190	2194	2198	38.00
6.90	2202	2206	2210	2213	2217	2221	2225	2229	2232	2236	38.00
7.00	2240	2244	2248	2252	2256	2260	2264	2268	2272	2276	40.00
7.10	2280	2284	2288	2292	2296	2300	2304	2308	2312	2316	40.00
7.20	2320	2324	2328	2332	2336	2340	2344	2348	2352	2356	40.00
7.30	2360	2364	2368	2372	2376	2380	2384	2388	2392	2396	40.00
7.40	2400	2404	2407	2411	2415	2419	2423	2427	2431	2435	39.00
7.50	2439	1443	2447	2451	2455	2459	2463	2467	2472	2476	41.00
7.60	2480	2484	2488	2492	2496	2500	2504	2508	2512	2516	40.00
7.70	2520	2524	2528	2532	2536	2540	2544	2548	2552	2556	40.00
7.80	2560	2564	2568	2572	2576	2580	2584	2588	2592	2596	40.00
7.90	2600	2604	2608	2612	2616	2620	2624	2628	2632	2636	40.00
8.00	2640	2644	2648	2653	2657	2661	2665	2669	2673	2678	42.00
8.10	2682	2686	2690	2694	2698	2703	2707	2711	2715	2719	42.00
8.20	2724	2728	2732	2736	2740	2744	2749	2753	2757	2761	41.00
8.30	2765	2770	2774	2778	2782	2786	2791	2795	2799	2803	42.00
8.40	2807	2811	2816	2820	2824	2828	2832	2837	2841	2845	42.00
8.50	2849	2853	2858	2862	2866	2870	2874	2879	2883	2887	42.00
8.60	2891	2895	2900	2904	2908	2912	2917	2921	2925	2929	42.00
8.70	2933	2938	2942	2946	2950	2954	2959	2963	2967	2971	43.00
8.80	2976	2980	2984	2988	2992	2997	3001	3005	3009	3014	42.00
8.90	3018	3022	3026	3030	3035	3039	3043	3047	3052	3056	42.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
DD: 3 TYPE: 001 RATING NO: 08
START DATE/TIME: 10-01-92 (0015)

05470500
SQUAW CREEK AT AMES, IA
OFFSET: 1.00
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND						(EXPANDED PRECISION)				DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
9.00	3060	3067	3074	3081	3088	3095	3102	3109	3116	3124	71.00
9.10	3131	3138	3145	3152	3159	3166	3173	3181	3188	3195	71.00
9.20	3202	3209	3217	3224	3231	3238	3245	3253	3260	3267	72.00
9.30	3274	3282	3289	3296	3303	3311	3318	3325	3333	3340	73.00
9.40	3347	3355	3362	3369	3377	3384	3391	3399	3406	3413	74.00
9.50	3421	3428	3436	3443	3451	3458	3465	3473	3480	3488	74.00
9.60	3495	3503	3510	3518	3525	3533	3540	3548	3555	3563	75.00
9.70	3570	3578	3585	3593	3601	3608	3616	3623	3631	3639	76.00
9.80	3646	3654	3661	3669	3677	3684	3692	3700	3707	3715	77.00
9.90	3723	3730	3738	3746	3754	3761	3769	3777	3784	3792	77.00
10.00	3800	3809	3819	3828	3838	3847	3856	3866	3875	3885	94.00
10.10	3894	3904	3913	3923	3932	3942	3951	3961	3971	3980	96.00
10.20	3990	3999	4009	4019	4028	4038	4048	4057	4067	4077	97.00
10.30	4087	4096	4106	4116	4126	4135	4145	4155	4165	4175	98.00
10.40	4185	4195	4204	4214	4224	4234	4244	4254	4264	4274	99.00
10.50	4284	4294	4304	4314	4324	4334	4344	4354	4364	4374	101.0
10.60	2385	4395	4405	4415	4425	4435	4446	4456	4466	4476	102.0
10.70	4487	4497	4507	4517	4528	4538	4548	4559	4569	4579	103.0
10.80	4590	4600	4611	4621	4631	4642	4652	4663	4673	4684	104.0
10.90	4694	4705	4715	4726	4736	4747	4758	4768	4779	4789	106.0
11.00	4800	4811	4822	4834	4845	4856	4868	4879	4890	4902	113.0
11.00	4913	4925	4936	4947	4959	4970	4982	4993	5005	5016	115.0
11.20	5028	5039	5051	5062	5074	5086	5097	5109	5121	5132	116.0
11.30	5144	5156	5167	5179	5191	5203	5214	5226	5238	5250	118.0
11.40	5262	5273	5285	5297	5309	5321	5333	5345	5357	5369	119.0

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
05470500 DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
SQUAW CREEK AT AMES, IA DD: 3 TYPE: 001 RATING NO: 08
OFFSET: 1.00 START DATE/TIME: 10-01-92 (0015)
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND						(EXPANDED PRECISION)				DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
11.50	5381	5393	5405	5417	5429	5441	5453	5465	5477	5489	121.0
11.60	5502	5514	5526	5538	5550	5563	5575	5587	5599	5612	122.0
11.70	5624	5636	5649	5661	5673	5686	5698	5710	5723	5735	124.0
11.80	5748	5760	5773	5785	5798	5810	5823	5835	5848	5860	125.0
11.90	5873	5886	5898	5911	5924	5936	5949	5962	5974	5987	127.0
12.00	6000	6011	6023	6034	6046	6057	6069	6080	6092	6103	115.0
12.10	6115	6126	6138	6150	6161	6173	6184	6196	6208	6219	116.0
12.20	6231	6243	6254	6266	6278	6289	6301	6313	6324	6336	117.0
12.30	6348	6360	6372	6383	6395	6407	6419	6431	6443	6454	118.0
12.40	6466	6478	6490	6502	6514	6526	6538	6550	6562	6574	120.0
12.50	6586	6598	6610	6622	6634	6646	6658	6670	6682	6694	120.0
12.60	6706	6718	6731	6743	6755	6767	6779	6791	6804	6816	122.0
12.70	6828	6840	6852	6865	6877	6889	6902	6914	6926	6938	123.0
12.80	6951	6963	6976	6988	7000	7013	7025	7038	7050	7062	124.0
12.90	7075	7087	7100	7112	7125	7137	7150	7162	7175	7187	125.0
13.00	7200	7215	7230	7245	7260	7275	7291	7306	7321	7336	151.0
13.10	7351	7367	7382	7397	7412	7428	7443	7458	7474	7489	154.0
13.20	7505	7520	7533	7551	7566	7582	7597	7613	7629	7644	155.0
13.30	7660	7675	7691	7707	7722	7738	7754	7770	7785	7801	157.0
13.40	7817	7833	7849	7864	7880	7896	7912	7928	7944	7960	159.0
13.50	7976	7992	8008	8024	8040	8056	8072	8088	8104	8121	161.0
13.60	8137	8153	8169	8185	8202	8218	7234	8251	8267	8283	163.0
13.70	8300	8316	8332	8349	8365	8382	8398	8415	8431	8448	164.0
13.80	8464	8481	8498	8514	8531	8548	8564	8581	8598	8614	167.0
13.90	8631	8648	8665	8682	8699	8715	8732	8749	8766	8783	169.0

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
05470500
SQUAW CREEK AT AMES, IA
DD: 3 TYPE: 001 RATING NO: 08
OFFSET: 1.00
START DATE/TIME: 10-01-92 (0015)
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	.05	(EXPANDED PRECISION) .06	.07	.08	.09	DIFF IN Q PER TENTH FT
14.00	8800	8820	8840	8861	8881	8901	8922	8942	8963	8983	204.0
14.10	9004	9024	9045	9065	9086	9107	9127	9148	9169	9190	207.0
14.20	8211	9231	9252	9273	9294	9315	9336	8357	9378	9399	210.0
14.30	9421	9442	9463	9484	9505	9527	9548	8569	9591	9612	213.0
14.40	9634	9655	9677	9698	9720	9741	9763	9785	9806	9828	216.0
14.50	9850	9872	9894	9917	9939	9961	9983	10010	10030	10050	220.0
14.60	10070	10100	10120	10140	10160	10190	10210	10230	10250	10280	230.0
14.70	10300	10320	10350	10370	10390	10410	10440	10460	10480	10510	230.0
14.80	10530	10550	10580	10600	10620	10650	10670	10690	10720	10740	230.0
14.90	10760	10790	10810	10830	10860	10880	10900	10930	10950	10980	240.0
15.00	11000	11030	11060	11090	11110	11140	11170	11200	11230	11260	290.0
15.10	11290	11320	11350	11380	11410	11440	11460	11490	11520	11550	290.0
15.20	11580	11610	11640	11670	11700	11730	11760	11790	11820	11850	300.0
15.30	11880	11910	11940	11970	12000	12040	12070	12100	12130	12160	310.0
15.40	12190	12220	12250	12280	12310	12340	12370	12410	12440	12470	310.0
15.50	12500	12520	12550	12570	12590	12620	12640	12660	12690	12710	230.0
15.60	12730	12760	12780	12810	12830	12850	12880	12900	12920	12950	240.0
15.70	12970	13000	13020	13040	13070	13090	13120	13140	13160	13190	240.0
15.80	13210	13240	13260	13280	13310	13330	13360	13380	13410	13430	240.0
15.90	13450	13480	13500	13530	13550	13580	13600	13630	13650	13680	250.0
16.00	13700	13730	13770	13800	13840	13870	13910	13940	13980	14010	350.0
16.10	14050	14080	14120	14150	14190	14220	14260	14290	14330	14360	350.0
16.20	14400	14440	14470	14510	14540	14580	14620	14650	14690	14720	360.0
16.30	14760	14800	14830	14870	14910	14940	14980	15020	15050	15090	370.0
16.40	15130	15160	15200	15240	15280	15310	15350	15390	15420	15460	370.0

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE TYPE: LOG
05470500 DATE PROCESSED: 09-01-1994 @ 11:04 BY BNATIONS
SQUAW CREEK AT AMES, IA DD: 3 TYPE: 001 RATING NO: 08
OFFSET: 1.00 START DATE/TIME: 10-01-92 (0015)
LATITIDE 420121 LONGITUDE 0933745 DRAINAGE AREA 204.00 DATUM 881.00 STATE 19 COUNTY 169
LAST UPDATED BY VEMILLER ON 02-10-1994 @ 10:50:41

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
16.50	15500	15540	15570	15610	15650	15680	15720	15760	15790	15830	370.0
16.60	15870	15900	15940	15980	16020	16050	16090	16130	16170	16200	370.0
16.70	16240	16280	16320	16350	16390	16430	16470	16510	16540	16580	380.0
16.80	16620	16660	16700	16740	16770	16810	16850	16890	16930	16970	390.0
16.90	17010	17050	17090	17120	17160	17200	17240	17280	17320	17360	390.0
17.00	17400	17430	17470	17500	17540	17570	17610	17640	17680	17710	350.0
17.10	17750	17790	17820	17860	17890	17930	17960	18000	18030	18070	360.0
17.20	18110	18140	18180	18210	18250	18280	18320	18360	18390	17430	360.0
17.30	18470	18500	18540	18570	18610	18650	18680	18720	18760	18790	360.0
17.40	18830	18870	18900	18940	18980	19010	19050	19090	19130	19160	370.0
17.50	19200	19240	19290	19330	19380	19420	19470	19510	19560	19600	440.0
17.60	19640	19690	19730	19780	19820	19870	19920	19960	20010	20050	460.0
17.70	20100	20140	20190	20230	20280	20330	20370	20420	20460	20510	460.0
17.80	20560	20600	20650	20700	20740	20790	20840	20880	20930	20980	460.0
17.90	21020	21070	21120	21170	21210	21260	21310	21360	21400	21450	480.0
18.00	21500	21550	21600	21650	21700	21750	21800	21850	21900	21950	500.0
18.10	22000	22050	22100	22150	22200	22250	22300	22350	22400	22450	500.0
18.20	22500	22550	22600	22650	22700	22750	22810	22860	22910	22960	510.0
18.30	23010	23060	23110	23170	23220	23270	23320	23370	23430	23480	520.0
18.40	23530	23580	23640	23690	23740	23800	23850	23900	23960	24010	530.0
18.50	24060	24120	24170	24220	24280	24330	24380	24440	24490	24550	540.0
18.60	24600										

APPENDIX C. SQUAW CREEK HEC-1 MODEL INPUTS

An example of the HEC-1 model input file will be listed in the next pages. Parameters that can and should be changed in the event of a flooding situation will be **bolded.** Following the input file example will be a description of the file inputs and a listing of acceptable input values for the input parameters.

Using COED, an editing program available from the US Army Corps of Engineers, the following type of input file is created for use by the HEC-1 modeling program.

Example HEC-1 Model Input File

```
***FREE***
ID  Squaw Creek Basin Response Model  Ames, IA
ID  Head of creek to junction with Skunk River
ID  Karla K. Tebben  10/3/94  AMC II.5
*DIAGRAM
IT  30 08JUL93 000,  , 12JUL93 000
IO  5
PG  43 0
IN  60 08JUL93 000
PI  0  0  0  0  0  0  0.60  0.10  0  0
PI  0  0  0  0  0  0  0  0  0  0
PI  1.60  0.40  0  0.70  1.70  0.10  0.10  0  0  0
PI  0  0  0  0  0  0  0  0  0  0
PG  11 0
IN  60 08JUL93 000
PI  0  0  0  0  0  0  0  1.00  0.10  0
PI  0  0  0  0  0  0  0  0  0  0
PI  0.40  0.60  0  0.30  0.10  0.70  0.20  0  0  0
PI  0  0  0  0  0  0  0  0  0  0
PG  10 0
IN  60 08JUL93 000
PI  0  0  0  0  0  0.40  0.40  0  0  0
PI  0  0  0  0  0  0  0  0  0  0  1.00
PI  1.70  0.10  0.90  1.50  0.20  0.10  0  0  0  0
PI  0  0.10  0  0  0  0  0  0  0  0
PG  38 0
```

```
IN  60 08JUL93 000
PI  0  0  0  0  0  0  0.90  0.10  0.10  0
PI  0  0  0  0  0  0  0  0  0  0
PI  1.40  0.40  0.10  0.60  1.10  0.10  0  0  0  0
PI  0  0.10  0  0  0  0  0  0  0  0
KK  SUBA
KO  5
BA  17.91
PR  38  11  10
PW  0.0022  0.8526  0.1452
LS  , , 87
UD  63
KK  ROUTE1
KM  ROUTE A TO B OUTLET
KO  5
RM  -1  1.6  0.20
KK  SUBB1
KO  5
BA  18.10
PR  38  10
PW  0.5530  0.4470
LS  ,  , 87
UD  7.9
KK  SUBB2
KO  5
BA  20.66
PR  11  38
PW  0.3504  0.6496
LS  ,  , 87
UD  6.8
KK  COMB1
KM  COMBINE A, B1, AND B2
HC  3
KK  ROUTE2
```

```
KM  ROUTE COMBINED FLOW TO C OUTLET
KO  5
RM  -1  2.9  0.20
KK  SUBC1
KO  4
BA  15.62
PR  38  10
PW  0.9821  0.0179
LS  , , 84
UD  5.0
KK  SUBC2
KO  5
BA  14.17
PR  38
PW  1
LS  , , 85
UD  5.2
KK  COMB2
KM  COMBINE FLOW WITH C1 AND C2
KO  0  2
HC  3
KK  ROUTE3
KM  ROUTE COMBINED FLOW TO D OUTLET
KO  5
RM  -1  2.9  0.20
KK  SUBD1
KO  4
BA  15.88
PR  38  43  10
PW  0.4466  0.3558  0.1996
LS  , , 85
UD  9.5
KK  SUBD2
KO  5
```

```
BA  14.79
PR  43  10
PW  0.5477  0.4523
LS  , , 85
UD  5.3
KK  SUBD3
KO  5
BA  9.08
PR  38  43
PW  0.0374  0.9626
LS  , , 85
UD  5.0
KK  SUBD4
KO  5
BA  18.72
PR  43  38
PW  0.1143  0.8857
LS  , , 85
UD  5.7
KK  COMB3
KM  COMBINE FLOW WITH D1, D2, D3, AND D4
KO  5
HC 5
KK  ROUTE4
KM  ROUTE FLOW TO E1 AND E2 OUTLET
KO  4
RM  -1  1.5  0.20
KK  SUBE1
KO  5
BA  6.35
PR  43
PW  1
LS  , ,84
UD  1.0
```

```
KK SUBE2
KO  5
BA  10.41
PR  43  38
PW  0.4832  0.5168
LS  , , 86
UD  4
KK  COMB4
KM  COMBINE FLOW WITH E1 AND E2
KO  0  2
HC  3
KK  ROUTE5
KM  ROUTE FLOW TO E3 AND E4 OUTLET
KO  5
RM  -1  2.1  0.20
KK  SUBE3
KO  5
BA  18.59
PR  43
PW  1
LS  , , 84
UD  4.7
KK  SUBE4
KO  5
BA  5.20
PR  43
PW  1
LS  , , 86
UD  4.0
KK  COMB5
KM  COMBINE FLOW WITH E3 AND E4
KO  5
HC  3
KK  ROUTE 6
```

```
KM  ROUTE FLOW TO LW GAGE
KO  5
RM  -1  2.2  0.20
KK  SUBF
KO  5
BA  15.36
BF  540  -0.26  1.055
PR  43
PW  1
LS  , , 83
UD  6.3
KK  COMB6
KM  COMBINE FLOW WITH F
KO  4
HC  2
KK  COMP1
KO  1
KM  COMPARE ACTUAL TO COMPUTED HYDROGRAPHS @ LW
IN  60 09JUL93 000
QO  3510  3951  5086  5748  6478  6610  10690  17470  23110  23580
QO  21800  19820  17610  16390  14760  13410  12620  10350  9939  8715
QO  7992  7551  6887  6622  6231
KK  ROUTE7
KM  ROUTE FLOW TO SKUNK RIVER
KO  5
RM  -1  1.2  0.20
KK  SUBG
KO  5
BA  16.62
PR  43
PW  1
LS  , , 83
UD  5.2
KK  COMB7
```

```
KM  COMBINE FLOW WITH G
KO  5
HC  2
ZZ
```

Explanation of Line Records and Ranges of Values

The following is a listing of the two letter line record delineators and the corresponding input parameters used in the above HEC-1 model input file. Those records that will be changed on a regular basis are listed first with their respective ranges of associated values. Those records that will not be regularly changed will also be listed with an explanation of the values associated with them. The information for these explanations comes from a HEC-1 user manual published by the US Army Corps of Engineers (1987).

Records That Will Be Changed

ID <Information concerning job>

The ID record is required to begin the job. The ID record lists information about the model to be run, such as basin name, programmer name, date of run, date of storm event, etc.

IT <NMIN> <IDATE> <ITIME> , ,<NDDATE> <NDTIME>

The IT record is required to begin the job. The IT record defines the time interval to be used for computation, starting time and date, and ending time and date.

<NMIN> = Integer number of minutes in computation interval
= 60 for hourly computation
= 30 for every thirty minutes
Minimum value is 1 minute
<IDATE> = Day, month and year for the beginning of the first time interval
Example: 08JUL93 would be entered for July 8, 1993. No runoff calculations are made for precipitation preceding this date.
Use 3-character lettering only for the month.
<ITIME> = Integer number for hour and minute of the beginning of the first time interval. Example: 1700 would be entered for 5:00 p.m.
No runoff calculation are made for precipitation preceding this time.
<NDDATE> =Day, month and year for the end of the required hydrograph

computations. The same format is used as for IDATE.

<NDTIME> = Integer number for the ending time of the hydrograph computations. The same format is used as for ITIME.

IN <JMIN> <JDATE> <JTIME>

The IN record is used to define the time interval and starting time and date for the precipitation or true stream gage data that follows it for each of the four rain gage stations or three stream gages used in the model development.

<JMIN> = Integer number of minutes between precipitation readings.
= 60 for hourly data
= 15 for 15-minute data
<JDATE> = Day, month and year of the beginning of the precipitation information. Example: 08JUL93 would be July 8, 1993
<JTIME> = Integer number for the beginning time of the precipitation information. Example: 1830 would be 6:30 p.m.

PI <PRCP> <PRCP> <PRCP> etc.

The PI record is used to input precipitation amounts in the intervals specified in the IN record starting at the time and date specified in the IN record. For example, if the IN record had a time interval of 60, hourly precipitation data in inches or mm would be entered on the PI card starting at the time and date listed in the IN record. Up to 10 numbers may be listed after each PI record up to a total of 300 numbers over 30 lines.

It should be noted that the precipitation amounts in this HEC-1 model are hourly data for Ames 8WSW (PG 43), Story City (PG 38), Webster City (PG 11), and Ogden (PG 10). Data for these gages are obtained from the National Climatic Data Center and are not available at this time on an hourly real-time basis. Hourly data for these gages is available eight to nine months after the storm event. For real-time flood prediction, the model will need to be altered to make use of a source of real-time precipitation data. In this case, it would be in the user's best interest to obtain the full documentation for the HEC-1 model from the US Army Corps of Engineers before proceeding with the alteration of the model.

LS , , <SCSCN>

The LS record is used to enter the curve number for the subbasin into the model. The subbasin with which the LS record is associated would be that listed on the KK record above the LS record in question. Curve number values for the subbasins in the model can be found in Table18 earlier in this report. Based on calibration and verification modeling for the Squaw Creek basin, curve numbers corresponding to an AMC II.5 are a good place to start in a flooding situation. Curve numbers between those listed also may be used to help the model response more closely match the true basin response measured by the stream gage data.

QO <STRQ>

The QO records are used to input the true stream hydrograph data as measured by the stream gages on the basin. The hydrograph intervals, and start date and time are specified on the preceding IN record. The hydrograph flows should be entered in cubic feet per second or cubic meters per second beginning at the starting date and time indicated on the IN record. If the measured hydrograph does not extend to the begin or end at the same time as the modeled hydrograph, the first or last value will be repeated as necessary to produce a hydrograph for the full time of the modeled hydrograph.

BF <STRTQ> <QRCSN> <RTIOR>

The BF records are used to input the baseflow in the stream prior to the storm event and the recession parameters for baseflow.

<STRTQ> = Flow in the basin at the gaging station of question at the start of the storm in cubic feet per second or cubic meters per second.

<QRCSN> = + number for flow in cubic feet per second below which baseflow recession occurs in accordance with the recession constant RTIOR.

= - number to signify the ratio by which the peak discharge is multiplied to obtain QRCSN. This has been set to -0.26 which says that the discharge at which recession flow begins is 26% of the peak discharge.

<RTIOR> = Recession flow constant computed by the equation:

$$RTIOR = (Qa/Qb)^{\wedge}(1/dt)$$

where Qb is the recession flow that occurs dt hours after recession flow Qa. This has been set equal to 1.055 in the model based on recession curves from basin hydrographs.

Records That Will Not Be Changed

IO <IPRT>

The IO record is used to control the output for the entire job. It can be overridden by a KO record later in the job.

<IPRT> = 0, 1, or 2 to print all output created by the modeling program
= 3 to print input data and intermediate and master summaries
= 4 to print input data and master summary
= 5 to print job specification and master summary only

PG <ISTAN> <PRCPN>

The PG records are used to identify the type and location of the precipitation data that will follow it.

<ISTAN> = Precipitation gaging station identifier
= 43 for Ames 8WSW
= 38 for Story City
= 11 for Webster City
= 10 for Ogden
<PRCPC> = 0 if the total storm precipitation will be computed from PI or PC records. This is what is currently used in the model.
= + number of total storm precipitation in inches or mm for the station during the time interval specified in the IN record.

KK <ISTAQ>

The KK record signals the beginning of a new job step, and is required to move from one job step to the next. <ISTAQ> is an alphanumeric identifier for each job step and must be unique to that step only.

KO <JPRT> <JPLT>

The KO record is used to define the output for a specified job step. It overrides the IO record until the next KK record is read.

<JPRT> = 0 to use the print control specified on the IO record
= 1 or 2 to print all of the output for the job step
= 3 to print input data and summaries for the job step

= 4 to print basin input data only for the job step
= 5 to have no printout for the job step
<JPLT> = 0 or Blank to use the plot control specified on the IO card
= 1 to have no plots printed for this job step
= 2 to have the computed hydrograph for this job step plotted

KM <MESSAGE>

The KM record is used to add a message to remind the user of the process occurring during a particular job step.

BA <AREA>

The BA record specifies the subbasin drainage area in square miles or square kilometers.

PR <ISTR> <ISTR> etc.

The PR record identifies which precipitation gaging stations apply to the subbasin in the job step. Up to five precipitation gaging stations may be specified.

<ISTR> = 43 for Ames 8WSW
= 38 for Story City
= 11 for Webster City
= 10 for Ogden

PW <WGT> <WGT> etc.

The PW record lists the relative weights to be assigned to the precipitation gages identified in the PR record. The value is entered in decimal form. For example, if the Ames 8WSW gage accounted for 28% of the rainfall in the subbasin according to the Theissen polygon, a value of 0.28 would be entered on this record to correspond to the gage order in the PR record. The percentages used for the subbasins are listed on Table 20 earlier in this report.

UD <TLAG>

The UD record is used to input the subbasin lag time in hours. The lag times used and the possible ranges for lag times are listed in Table19 earlier in this report.

RM <NSTPS> <AMSKK> <X>

The RM record inputs the parameters necessary for Muskingame routing of the stream flow from one node to the next.

<NSTPS> = + integer to specify the number of steps (equal to the number of subreaches) for the Muskingame routing.
= -1 for the number of steps to be optimized or the number of steps must have been previously supplied.
<AMSKK> = + number to specify the Muskingame K coefficient in hours for the entire reach. The program automatically calculates the subreach K as AMSKK/NSTPS. The values for this parameter were obtained from Glanville's original model and calculated according to the procedure he outlined in his thesis for the added reach in the revised model. (Glanville, 1987, pp. 102-104)
<X> = + number for the Muskingame routing X coefficient. Glanville states in his thesis that the value of 0.20 was reasonable for the Squaw Creek basin. (Glanville, 1987, p. 102)

HC <ICOMB>

The HC records specify the number of previously computed hydrographs to be combined in the job step.

ZZ

The ZZ record signals the end of the input file for the HEC-1 program.

APPENDIX D. EXAMPLE OF SQUAW CREEK HEC-1 MODEL OUTPUT

```
1*****************************************                  ***************************************
*                  *                            *           *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                          *  U.S. ARMY CORPS OF ENGINEERS    *
*         FEBRUARY 1981          *                  * THE HYDROLOGIC ENGINEERING CENTER  *
*       REVISED 01 JUN 88        *                    *       609 SECOND STREET          *
*                  *                            *    DAVIS, CALIFORNIA 95616      *
*  RUN DATE  05/22/1996  TIME  20:12:04 *                    *       (916) 551-1748          *
*                  *                            *           *
****************************************                  **************************************


              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


1                               HEC-1 INPUT                          PAGE  1

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

*** FREE ***
       1      ID  Squaw Creek Basin Response Model Ames, IA
       2      ID  Head of creek to junction with Skunk River
       3      ID  Karla K. Tebben 2/18/96  7/17/93 flood AMCII.5-2
       4      ID  No baseflow, File:93FL3R25 Actual at LW included
              *DIAGRAM
       5      IT     30 16JUL93   2300       20JUL93    000
       6      IO      4
       7      PG     43     0
       8      IN     60 16JUL93   2300
       9      PI   0.40     0     0     0  1.90  0.60     0     0     0     0
      10      PI   0.10     0     0     0     0     0     0     0     0     0
      11      PG     11     0
      12      IN     60 16JUL93   2300
      13      PI      0     0  0.10  0.20     0     0  0.90  0.90  0.50  0.50
      14      PI   0.40  0.10     0     0     0     0     0     0     0     0
      15      PG     10     0
      16      IN     60 16JUL93   2300
      17      PI      0     0     0  0.20  0.10  0.10  0.10     0     0     0
      18      PI      0     0     0     0     0     0     0     0     0     0
      19      PG     38     0
      20      IN     60 16JUL93   2300
      21      PI      0  0.40     0     0  1.90  1.00  0.40  0.10     0     0
```

```
        22      PI   0    0    0    0    0    0    0    0    0    0

        23      KK  SUBA
        24      KO    4
        25      BA  17.91
        26      PR   38   11   10
        27      PW 0.0022 0.8526 0.1452
        28      LS         85
        29      UD   6.3

        30      KK  ROUTE1
        31      KM  ROUTE A TO B OUTLET
        32      KO    4
        33      RM   -1   1.6   .20

        34      KK  SUBB1
        35      KO    4
        36      BA  18.10
        37      PR   38   10
        38      PW  .5530  .4470
        39      LS         85
        40      UD   7.9

        41      KK  SUBB2
        42      KO    4
        43      BA  20.66
        44      PR   11   38
        45      PW  .3504  .6496
        46      LS         85
        47      UD   6.8
1                         HEC-1 INPUT                        PAGE  2

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


        48      KK  COMB1
        49      KM  COMBINE A, B1, AND B2
        50      HC    3

        51      KK  ROUTE2
        52      KM  ROUTE COMBINED FLOW TO C OUTLET
        53      KO    4
        54      RM   -1   2.9   .20

        55      KK  SUBC1
        56      KO    4
        57      BA  15.62
        58      PR   38   10
        59      PW  .9821  .0179
        60      LS         82
        61      UD   5.0

        62      KK  SUBC2
        63      KO    4
        64      BA  14.17
        65      PR   38
        66      PW    1
        67      LS         83
        68      UD   5.2

        69      KK  COMB2
        70      KM  COMBINE FLOW WITH C1 AND C2
        71      KO    0    2
        72      HC    3
```

```
      73      KK  ROUTE3
      74      KM  ROUTE COMBINED FLOW TO D OUTLET
      75      KO    4
      76      RM    -1   2.9    .2

      77      KK  SUBD1
      78      KO    4
      79      BA  15.88
      80      PR    38    43     10
      81      PW  .4446  .3558  .1996
      82      LS          83
      83      UD    9.5

      84      KK  SUBD2
      85      KO    4
      86      BA  14.79
      87      PR    43    10
      88      PW  .5477  .4523
      89      LS          83
      90      UD    5.3
1                             HEC-1 INPUT                              PAGE  3

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


      91      KK  SUBD3
      92      KO    4
      93      BA   9.08
      94      PR    38    43
      95      PW  .0374  .9626
      96      LS          83
      97      UD    5.0

      98      KK  SUBD4
      99      KO    4
     100      BA  18.72
     101      PR    43    38
     102      PW  .1143  .8857
     103      LS          83
     104      UD    5.7

     105      KK  COMB3
     106      KM  COMBINE FLOW WITH D1,D2,D3 AND D4
     107      KO    4
     108      HC    5

     109      KK  ROUTE4
     110      KM  ROUTE FLOW TO E1 AND E2 OUTLET
     111      KO    4
     112      RM    -1    1.5    .20

     113      KK  SUBE1
     114      KO    4
     115      BA   6.35
     116      PR    43
     117      PW    1
     118      LS          82
     119      UD    1.0

     120      KK  SUBE2
     121      KO    4
     122      BA  10.41
     123      PR    43    38
     124      PW  .4832  .5168
     125      LS          84
```

```
 126       UD    4

 127       KK  COMB4
 128       KM  COMBINE FLOW WITH E1 AND E2
 129       KO    0    2
 130       HC    3

 131       KK  ROUTE5
 132       KM  ROUTE FLOW TO E3 AND E4 OUTLET
 133       KO    4
 134       RM    -1   2.1   .20
1                          HEC-1 INPUT                        PAGE  4

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


 135       KK  SUBE3
 136       KO    4
 137       BA  18.59
 138       PR    43
 139       PW    1
 140       LS         82
 141       UD   4.7

 142       KK  SUBE4
 143       KO    4
 144       BA   5.20
 145       PR    43
 146       PW    1
 147       LS         84
 148       UD   4.0

 149       KK  COMB5
 150       KM  COMBINE FLOW WITH E3 AND E4
 151       KO    4
 152       HC    3

 153       KK  ROUTE6
 154       KM  ROUTE FLOW TO LW GAGE
 155       KO    4
 156       RM    -1   2.2   0.20

 157       KK   SUBF
 158       KO    4
 159       BA  15.36
 160       PR    43
 161       PW    1
 162       LS         81
 163       UD   6.3

 164       KK  COMB6
 165       KM  COMBINE FLOW WITH F
 166       KO    3    2
 167       HC    2

 168       KK  COMP1
 169       KO    1
 170       KM  Compare actual to computed hydrograph @ LW
 171       IN   180 17JUL93   0000
 172       QO    0     0   2360   4079   6421  10753   9437   7468   5769   4756
 173       QO  3864  3116  2374   1906   1415    906    575    327     75      0

 174       KK  ROUTE7
 175       KM  ROUTE FLOW TO SKUNK RIVER
 176       KO    4
```

```
 177     RM   -1   1.2   0.20
1                          HEC-1 INPUT                          PAGE 5

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


  178     KK   SUBG
  179     KO     4
  180     BA   16.62
  181     PR    43
  182     PW     1
  183     LS          81
  184     UD    5.2

  185     KK   COMB7
  186     KM   COMBINE FLOW WITH G
  187     KO     4
  188     HC     2
  189     ZZ
1
         SCHEMATIC DIAGRAM OF STREAM NETWORK
INPUT
 LINE    (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

 NO.     (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

  23     SUBA
          V
          V
  30    ROUTE1
          .
          .
  34      .     SUBB1
          .       .
          .       .
  41      .       .     SUBB2
          .       .       .
          .       .       .
  48    COMB1.........................
          V
          V
  51    ROUTE2
          .
          .
  55      .     SUBC1
          .       .
          .       .
  62      .       .     SUBC2
          .       .       .
          .       .       .
  69    COMB2.........................
          V
          V
  73    ROUTE3
          .
          .
  77      .     SUBD1
          .       .
          .       .
  84      .       .     SUBD2
          .       .       .
          .       .       .
  91      .       .       .     SUBD3
          .       .       .       .
          .       .       .       .
```

```
 98     .     .     .     .    SUBD4
        .     .     .     .     .
        .     .     .     .     .
105    COMB3.............................................
        V
        V
109    ROUTE4
        .
        .
113     .    SUBE1
        .     .
        .     .
120     .     .    SUBE2
        .     .     .
        .     .     .
127    COMB4........................
        V
        V
131    ROUTE5
        .
        .
135     .    SUBE3
        .     .
        .     .
142     .     .    SUBE4
        .     .     .
        .     .     .
149    COMB5........................
        V
        V
153    ROUTE6
        .
        .
157     .    SUBF
        .     .
        .     .
164    COMB6............
        V
        V
174    ROUTE7
        .
        .
178     .    SUBG
        .     .
        .     .
185    COMB7............

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1*****************************************                 ****************************************
*                    *                   *                  *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                       *  U.S. ARMY CORPS OF ENGINEERS    *
*         FEBRUARY 1981          *                  * THE HYDROLOGIC ENGINEERING CENTER *
*        REVISED 01 JUN 88        *                  *        609 SECOND STREET        *
*                    *                   *   DAVIS, CALIFORNIA 95616    *
* RUN DATE  05/22/1996  TIME  20:12:04 *                      *        (916) 551-1748         *
*                    *                   *                  *
*****************************************                  ****************************************


              Squaw Creek Basin Response Model Ames, IA
              Head of creek to junction with Skunk River
              Karla K. Tebben 2/18/96  7/17/93 flood AMCII.5-2
```

```
              No baseflow, File:93FL3R25 Actual at LW included

 6 IO       OUTPUT CONTROL VARIABLES
              IPRNT          4  PRINT CONTROL
              IPLOT          0  PLOT CONTROL
              QSCAL          0.  HYDROGRAPH PLOT SCALE

 8 IN       TIME DATA FOR INPUT TIME SERIES
              JXMIN         60  TIME INTERVAL IN MINUTES
             JXDATE    16JUL93  STARTING DATE
             JXTIME       2300  STARTING TIME

12 IN       TIME DATA FOR INPUT TIME SERIES
              JXMIN         60  TIME INTERVAL IN MINUTES
             JXDATE    16JUL93  STARTING DATE
             JXTIME       2300  STARTING TIME

16 IN       TIME DATA FOR INPUT TIME SERIES
              JXMIN         60  TIME INTERVAL IN MINUTES
             JXDATE    16JUL93  STARTING DATE
             JXTIME       2300  STARTING TIME

20 IN       TIME DATA FOR INPUT TIME SERIES
              JXMIN         60  TIME INTERVAL IN MINUTES
             JXDATE    16JUL93  STARTING DATE
             JXTIME       2300  STARTING TIME

   IT       HYDROGRAPH TIME DATA
               NMIN         30  MINUTES IN COMPUTATION INTERVAL
              IDATE    16JUL93  STARTING DATE
              ITIME       2300  STARTING TIME
                 NQ        147  NUMBER OF HYDROGRAPH ORDINATES
             NDDATE    20JUL93  ENDING DATE
             NDTIME       0000  ENDING TIME
              ICENT         19  CENTURY MARK

            COMPUTATION INTERVAL     .50 HOURS
                TOTAL TIME BASE    73.00 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


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


       **************
       *            *
23 KK  *    SUBA    *
       *            *
       **************

24 KO       OUTPUT CONTROL VARIABLES
              IPRNT          4  PRINT CONTROL
              IPLOT          0  PLOT CONTROL
              QSCAL          0.  HYDROGRAPH PLOT SCALE
```

```
         SUBBASIN RUNOFF DATA

25 BA        SUBBASIN CHARACTERISTICS
              TAREA       17.91  SUBBASIN AREA

           PRECIPITATION DATA

26 PR           RECORDING STATIONS       38       11       10
27 PW                   WEIGHTS      .00     .85     .15

28 LS        SCS LOSS RATE
              STRTL         .35  INITIAL ABSTRACTION
             CRVNBR       85.00  CURVE NUMBER
              RTIMP         .00  PERCENT IMPERVIOUS AREA

29 UD        SCS DIMENSIONLESS UNITGRAPH
              TLAG        6.30  LAG

                                   ***

         PRECIPITATION STATION DATA

              STATION   TOTAL   AVG. ANNUAL    WEIGHT
                  38    3.80        .00        .00
                  11    3.60        .00        .85
                  10     .50        .00        .15

           TEMPORAL DISTRIBUTIONS

           STATION      38,  WEIGHT =   .00
                .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
                .50    .50    .20    .20    .05    .05    .00    .00    .00    .00
                .00    .00    .00    .00

           STATION      11,  WEIGHT =   .85
                .00    .00    .00    .00    .05    .05    .10    .10    .00    .00
                .00    .00    .45    .45    .45    .45    .25    .25    .25    .25
                .20    .20    .05    .05

           STATION      10,  WEIGHT =   .15
                .00    .00    .00    .00    .00    .00    .10    .10    .05    .05
                .05    .05    .05    .05    .00    .00    .00    .00    .00    .00
                .00    .00    .00    .00

                                     UNIT HYDROGRAPH
                                 65 END-OF-PERIOD ORDINATES
          30.     88.    167.    259.    380.    532.    707.    894.   1056.   1175.
        1260.   1310.   1320.   1312.   1272.   1209.   1138.   1058.    964.    856.
         736.    635.    556.    490.    430.    380.    340.    304.    268.    238.
         208.    183.    163.    143.    127.    112.     98.     87.     76.     67.
          60.     52.     47.     41.     36.     32.     28.     25.     22.     19.
          17.     15.     14.     13.     11.     10.      9.      8.      7.      6.
           5.      4.      3.      2.      1.


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


        **************
        *            *
30 KK   *   ROUTE1   *
        *            *
        **************
```

```
            ROUTE A TO B OUTLET

  32 KO       OUTPUT CONTROL VARIABLES
              IPRNT        4  PRINT CONTROL
              IPLOT        0  PLOT CONTROL
              QSCAL        0.  HYDROGRAPH PLOT SCALE

          HYDROGRAPH ROUTING DATA

  33 RM       MUSKINGUM ROUTING
              NSTPS      -1 NUMBER OF SUBREACHES
              AMSKK     1.60 MUSKINGUM K
                X      .20 MUSKINGUM X

                                 ***



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


        **************
        *          *
  34 KK   *    SUBB1  *
        *          *
        **************

  35 KO       OUTPUT CONTROL VARIABLES
              IPRNT        4  PRINT CONTROL
              IPLOT        0  PLOT CONTROL
              QSCAL        0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

  36 BA       SUBBASIN CHARACTERISTICS
              TAREA      18.10  SUBBASIN AREA

           PRECIPITATION DATA

  37 PR         RECORDING STATIONS       38      10
  38 PW                WEIGHTS      .55     .45

  39 LS       SCS LOSS RATE
              STRTL       .35  INITIAL ABSTRACTION
             CRVNBR      85.00  CURVE NUMBER
              RTIMP       .00  PERCENT IMPERVIOUS AREA

  40 UD       SCS DIMENSIONLESS UNITGRAPH
               TLAG       7.90  LAG

                                 ***

          PRECIPITATION STATION DATA

              STATION   TOTAL   AVG. ANNUAL    WEIGHT
                 38    3.80       .00       .55
                 10     .50       .00       .45

           TEMPORAL DISTRIBUTIONS

           STATION      38,  WEIGHT =   .55
              .00     .00     .20     .20     .00     .00     .00     .00     .95     .95
              .50     .50     .20     .20     .05     .05     .00     .00     .00     .00
              .00     .00     .00     .00
```

```
      STATION     10, WEIGHT =   .45
          .00    .00    .00    .00    .00    .00    .10    .10    .05    .05
          .05    .05    .05    .05    .00    .00    .00    .00    .00    .00
          .00    .00    .00    .00

                                 UNIT HYDROGRAPH
                              81 END-OF-PERIOD ORDINATES
     20.     49.     95.    151.    213.    291.    383.    488.    611.    731.
    837.    922.    995.   1036.   1064.   1071.   1068.   1059.   1020.    977.
    931.    880.    825.    759.    686.    607.    540.    480.    434.    392.
    353.    320.    291.    267.    243.    219.    200.    180.    160.    146.
    133.    120.    109.     99.     89.     80.     73.     66.     59.     54.
     49.     44.     40.     36.     33.     30.     27.     24.     22.     20.
     18.     16.     15.     13.     12.     11.     10.     10.      9.      8.
      7.      6.      6.      5.      4.      4.      3.      2.      2.      1.
      0.


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


        **************
        *            *
 41 KK  *    SUBB2   *
        *            *
        **************

 42 KO       OUTPUT CONTROL VARIABLES
             IPRNT          4  PRINT CONTROL
             IPLOT          0  PLOT CONTROL
             QSCAL         0.  HYDROGRAPH PLOT SCALE

        SUBBASIN RUNOFF DATA

 43 BA       SUBBASIN CHARACTERISTICS
             TAREA      20.66  SUBBASIN AREA

         PRECIPITATION DATA

 44 PR         RECORDING STATIONS       11      38
 45 PW                WEIGHTS      .35     .65

 46 LS       SCS LOSS RATE
             STRTL        .35  INITIAL ABSTRACTION
             CRVNBR     85.00  CURVE NUMBER
             RTIMP        .00  PERCENT IMPERVIOUS AREA

 47 UD       SCS DIMENSIONLESS UNITGRAPH
             TLAG        6.80  LAG

                              ***

        PRECIPITATION STATION DATA

             STATION   TOTAL   AVG. ANNUAL   WEIGHT
                11     3.60        .00         .35
                38     3.80        .00         .65

         TEMPORAL DISTRIBUTIONS

      STATION     11, WEIGHT =   .35
          .00    .00    .00    .00    .05    .05    .10    .10    .00    .00
```

```
             .00    .00    .45    .45    .45    .45

           STATION     38,  WEIGHT =   .65
             .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
             .50    .50    .20    .20    .05    .05

                                    UNIT HYDROGRAPH
                                  70 END-OF-PERIOD ORDINATES
          30.     84.    158.    248.    362.    497.    657.    847.   1021.   1175.
        1286.   1360.   1405.   1415.   1407.   1372.   1311.   1241.   1164.   1078.
         978.    860.    749.    649.    579.    515.    457.    406.    367.    330.
         294.    264.    233.    205.    185.    165.    146.    131.    116.    103.
          92.     81.     73.     65.     58.     52.     46.     41.     37.     33.
          29.     26.     23.     20.     18.     16.     15.     14.     12.     11.
          10.      9.      8.      7.      6.      5.      4.      3.      2.      1.


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


         **************
         *            *
  48 KK  *   COMB1    *
         *            *
         **************
                  COMBINE A, B1, AND B2

  50 HC         HYDROGRAPH COMBINATION
                ICOMP          3  NUMBER OF HYDROGRAPHS TO COMBINE

                                    ***


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


         **************
         *            *
  51 KK  *   ROUTE2   *
         *            *
         **************
                  ROUTE COMBINED FLOW TO C OUTLET

  53 KO         OUTPUT CONTROL VARIABLES
                IPRNT          4  PRINT CONTROL
                IPLOT          0  PLOT CONTROL
                QSCAL         0.  HYDROGRAPH PLOT SCALE

           HYDROGRAPH ROUTING DATA

  54 RM         MUSKINGUM ROUTING
                NSTPS         -1  NUMBER OF SUBREACHES
                AMSKK       2.90  MUSKINGUM K
                    X        .20  MUSKINGUM X

                                    ***


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***
```

```
          **************
          *            *
55 KK     *    SUBC1   *
          *            *
          **************

56 KO        OUTPUT CONTROL VARIABLES
              IPRNT          4  PRINT CONTROL
              IPLOT          0  PLOT CONTROL
              QSCAL          0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

57 BA        SUBBASIN CHARACTERISTICS
              TAREA       15.62  SUBBASIN AREA

           PRECIPITATION DATA

58 PR           RECORDING STATIONS        38        10
59 PW                    WEIGHTS        .98       .02

60 LS        SCS LOSS RATE
              STRTL         .44  INITIAL ABSTRACTION
             CRVNBR       82.00  CURVE NUMBER
              RTIMP         .00  PERCENT IMPERVIOUS AREA

61 UD        SCS DIMENSIONLESS UNITGRAPH
              TLAG         5.00  LAG

                                   ***

          PRECIPITATION STATION DATA

                 STATION    TOTAL    AVG. ANNUAL    WEIGHT
                     38      3.80        .00          .98
                     10       .50        .00          .02

           TEMPORAL DISTRIBUTIONS

           STATION     38,  WEIGHT =   .98
                .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
                .50    .50    .20    .20    .05    .05    .00    .00    .00    .00
                .00    .00    .00    .00

           STATION     10,  WEIGHT =   .02
                .00    .00    .00    .00    .00    .00    .10    .10    .05    .05
                .05    .05    .05    .05    .00    .00    .00    .00    .00    .00
                .00    .00    .00    .00

                                    UNIT HYDROGRAPH
                                 52 END-OF-PERIOD ORDINATES
            41.    134.    255.    413.    622.    872.   1103.   1278.   1388.   1432.
          1432.   1388.   1300.   1199.   1081.    937.    778.    648.    553.    471.
           403.    353.    303.    261.    220.    190.    162.    140.    119.    102.
            87.     74.     64.     55.     47.     40.     35.     29.     25.     21.
            19.     16.     14.     13.     11.      9.      8.      6.      5.      3.
             2.      1.

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***
```

```
     **************
     *            *
62 KK  *   SUBC2  *
     *            *
     **************

63 KO       OUTPUT CONTROL VARIABLES
            IPRNT        4  PRINT CONTROL
            IPLOT        0  PLOT CONTROL
            QSCAL       0.  HYDROGRAPH PLOT SCALE

         SUBBASIN RUNOFF DATA

64 BA       SUBBASIN CHARACTERISTICS
            TAREA      14.17  SUBBASIN AREA

          PRECIPITATION DATA

65 PR        RECORDING STATIONS       38
66 PW               WEIGHTS     1.00

67 LS       SCS LOSS RATE
            STRTL       .41  INITIAL ABSTRACTION
           CRVNBR     83.00  CURVE NUMBER
            RTIMP       .00  PERCENT IMPERVIOUS AREA

68 UD       SCS DIMENSIONLESS UNITGRAPH
             TLAG      5.20  LAG

                              ***

         PRECIPITATION STATION DATA

              STATION   TOTAL   AVG. ANNUAL   WEIGHT
                 38    3.80        .00        1.00

          TEMPORAL DISTRIBUTIONS

          STATION     38,  WEIGHT =  1.00
             .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
             .50    .50    .20    .20    .05    .05

                                 UNIT HYDROGRAPH
                               54 END-OF-PERIOD ORDINATES
       35.    111.    211.    340.    507.    711.    914.   1077.   1187.   1245.
     1255.   1243.   1173.   1094.   1003.    894.    764.    639.    540.    463.
      398.    343.    301.    259.    225.    190.    165.    142.    123.    106.
       91.     78.     66.     58.     49.     43.     37.     32.     27.     24.
       20.     18.     15.     13.     12.     10.      9.      8.      6.      5.
        4.      3.      2.      1.


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


     **************
     *            *
69 KK  *   COMB2  *
     *            *
     **************
              COMBINE FLOW WITH C1 AND C2
```

```
  71 KO       OUTPUT CONTROL VARIABLES
              IPRNT        4  PRINT CONTROL
              IPLOT        2  PLOT CONTROL
              QSCAL        0.  HYDROGRAPH PLOT SCALE

  72 HC       HYDROGRAPH COMBINATION
              ICOMP        3  NUMBER OF HYDROGRAPHS TO COMBINE

                                  ***
1                               STATION    COMB2

              (O) OUTFLOW
          0.     1000.     2000.     3000.     4000.     5000.     6000.     7000.        0.        0.        0.        0.        0.
DAHRMN PER
162300   1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
162330   2O         .         .         .         .         .         .         .         .         .         .         .         .
170000   3O         .         .         .         .         .         .         .         .         .         .         .         .
170030   4O         .         .         .         .         .         .         .         .         .         .         .         .
170100   5O         .         .         .         .         .         .         .         .         .         .         .         .
170130   6O         .         .         .         .         .         .         .         .         .         .         .         .
170200   7O         .         .         .         .         .         .         .         .         .         .         .         .
170230   8O         .         .         .         .         .         .         .         .         .         .         .         .
170300   9O         .         .         .         .         .         .         .         .         .         .         .         .
170330  10O         .         .         .         .         .         .         .         .         .         .         .         .
170400  11.O.......................................................................................................................
170430  12. O       .         .         .         .         .         .         .         .         .         .         .         .
170500  13.    O    .         .         .         .         .         .         .         .         .         .         .         .
170530  14.         .O        .         .         .         .         .         .         .         .         .         .         .
170600  15.         .      O  .         .         .         .         .         .         .         .         .         .         .
170630  16.         .         .   O     .         .         .         .         .         .         .         .         .         .
170700  17.         .         .         .  O      .         .         .         .         .         .         .         .         .
170730  18.         .         .         .         .O        .         .         .         .         .         .         .         .
170800  19.         .         .         .         .        O.         .         .         .         .         .         .         .
170830  20.         .         .         .         .         .    O    .         .         .         .         .         .         .
170900  21...........................................................O............................................................
170930  22.         .         .         .         .         .         .   O     .         .         .         .         .         .
171000  23.         .         .         .         .         .         .     O   .         .         .         .         .         .
171030  24.         .         .         .         .         .         .       O .         .         .         .         .         .
171100  25.         .         .         .         .         .         .       O .         .         .         .         .         .
171130  26.         .         .         .         .         .         .       O .         .         .         .         .         .
171200  27.         .         .         .         .         .         .      O  .         .         .         .         .         .
171230  28.         .         .         .         .         .         .    O    .         .         .         .         .         .
171300  29.         .         .         .         .         .         .   O     .         .         .         .         .         .
171330  30.         .         .         .         .         .         .  O      .         .         .         .         .         .
171400  31..............................................................O.........................................................
171430  32.         .         .         .         .         .         .O        .         .         .         .         .         .
171500  33.         .         .         .         .         .         .O        .         .         .         .         .         .
171530  34.         .         .         .         .         .         .O        .         .         .         .         .         .
171600  35.         .         .         .         .         .         O         .         .         .         .         .         .
171630  36.         .         .         .         .         .       O .         .         .         .         .         .         .
171700  37.         .         .         .         .         .      O  .         .         .         .         .         .         .
171730  38.         .         .         .         .         .    O    .         .         .         .         .         .         .
171800  39.         .         .         .         .         .O        .         .         .         .         .         .         .
171830  40.         .         .         .         .         O         .         .         .         .         .         .         .
171900  41..............................................O.........................................................................
171930  42.         .         .         .         .   O     .         .         .         .         .         .         .         .
172000  43.         .         .         .         .O        .         .         .         .         .         .         .         .
172030  44.         .         .         .        O.         .         .         .         .         .         .         .         .
172100  45.         .         .         .     O   .         .         .         .         .         .         .         .         .
172130  46.         .         .         .  O      .         .         .         .         .         .         .         .         .
172200  47.         .         .         O         .         .         .         .         .         .         .         .         .
172230  48.         .         .       O .         .         .         .         .         .         .         .         .         .
172300  49.         .         .    O    .         .         .         .         .         .         .         .         .         .
172330  50.         .         .  O      .         .         .         .         .         .         .         .         .         .
180000  51.....................O...................................................................................................
```

```
180030 52.    .    O.    .    .    .    .    .    .    .    .    .    .
180100 53.    .   O .    .    .    .    .    .    .    .    .    .    .
180130 54.    .  O  .    .    .    .    .    .    .    .    .    .    .
180200 55.    . O   .    .    .    .    .    .    .    .    .    .    .
180230 56.    .O    .    .    .    .    .    .    .    .    .    .    .
180300 57.    .O    .    .    .    .    .    .    .    .    .    .    .
180330 58.    O     .    .    .    .    .    .    .    .    .    .    .
180400 59.    O.    .    .    .    .    .    .    .    .    .    .    .
180430 60.   O .    .    .    .    .    .    .    .    .    .    .    .
180500 61....O.........................................................
180530 62.  O  .    .    .    .    .    .    .    .    .    .    .    .
180600 63.  O  .    .    .    .    .    .    .    .    .    .    .    .
180630 64.  O  .    .    .    .    .    .    .    .    .    .    .    .
180700 65. O   .    .    .    .    .    .    .    .    .    .    .    .
180730 66. O   .    .    .    .    .    .    .    .    .    .    .    .
180800 67. O   .    .    .    .    .    .    .    .    .    .    .    .
180830 68. O   .    .    .    .    .    .    .    .    .    .    .    .
180900 69. O   .    .    .    .    .    .    .    .    .    .    .    .
180930 70. O   .    .    .    .    .    .    .    .    .    .    .    .
181000 71.O............................................................
181030 72. O   .    .    .    .    .    .    .    .    .    .    .    .
181100 73. O   .    .    .    .    .    .    .    .    .    .    .    .
181130 74. O   .    .    .    .    .    .    .    .    .    .    .    .
181200 75.O    .    .    .    .    .    .    .    .    .    .    .    .
181230 76.O    .    .    .    .    .    .    .    .    .    .    .    .
181300 77.O    .    .    .    .    .    .    .    .    .    .    .    .
181330 78.O    .    .    .    .    .    .    .    .    .    .    .    .
181400 79.O    .    .    .    .    .    .    .    .    .    .    .    .
181430 80.O    .    .    .    .    .    .    .    .    .    .    .    .
181500 81.O............................................................
181530 82.O    .    .    .    .    .    .    .    .    .    .    .    .
181600 83.O    .    .    .    .    .    .    .    .    .    .    .    .
181630 84O     .    .    .    .    .    .    .    .    .    .    .    .
181700 85O     .    .    .    .    .    .    .    .    .    .    .    .
181730 86O     .    .    .    .    .    .    .    .    .    .    .    .
181800 87O     .    .    .    .    .    .    .    .    .    .    .    .
181830 88O     .    .    .    .    .    .    .    .    .    .    .    .
181900 89O     .    .    .    .    .    .    .    .    .    .    .    .
181930 90O     .    .    .    .    .    .    .    .    .    .    .    .
182000 91O.............................................................
182030 92O     .    .    .    .    .    .    .    .    .    .    .    .
182100 93O     .    .    .    .    .    .    .    .    .    .    .    .
182130 94O     .    .    .    .    .    .    .    .    .    .    .    .
182200 95O     .    .    .    .    .    .    .    .    .    .    .    .
182230 96O     .    .    .    .    .    .    .    .    .    .    .    .
182300 97O     .    .    .    .    .    .    .    .    .    .    .    .
182330 98O     .    .    .    .    .    .    .    .    .    .    .    .
190000 99O     .    .    .    .    .    .    .    .    .    .    .    .
190030 100O    .    .    .    .    .    .    .    .    .    .    .    .
190100 101O............................................................
190130 102O    .    .    .    .    .    .    .    .    .    .    .    .
190200 103O    .    .    .    .    .    .    .    .    .    .    .    .
190230 104O    .    .    .    .    .    .    .    .    .    .    .    .
190300 105O    .    .    .    .    .    .    .    .    .    .    .    .
190330 106O    .    .    .    .    .    .    .    .    .    .    .    .
190400 107O    .    .    .    .    .    .    .    .    .    .    .    .
190430 108O    .    .    .    .    .    .    .    .    .    .    .    .
190500 109O    .    .    .    .    .    .    .    .    .    .    .    .
190530 110O    .    .    .    .    .    .    .    .    .    .    .    .
190600 111O............................................................
190630 112O    .    .    .    .    .    .    .    .    .    .    .    .
190700 113O    .    .    .    .    .    .    .    .    .    .    .    .
190730 114O    .    .    .    .    .    .    .    .    .    .    .    .
190800 115O    .    .    .    .    .    .    .    .    .    .    .    .
190830 116O    .    .    .    .    .    .    .    .    .    .    .    .
```

```
190900 117O    .    .    .    .    .    .    .    .    .    .    .    .
190930 118O    .    .    .    .    .    .    .    .    .    .    .    .
191000 119O    .    .    .    .    .    .    .    .    .    .    .    .
191030 120O    .    .    .    .    .    .    .    .    .    .    .    .
191100 121O.............................................................
191130 122O    .    .    .    .    .    .    .    .    .    .    .    .
191200 123O    .    .    .    .    .    .    .    .    .    .    .    .
191230 124O    .    .    .    .    .    .    .    .    .    .    .    .
191300 125O    .    .    .    .    .    .    .    .    .    .    .    .
191330 126O    .    .    .    .    .    .    .    .    .    .    .    .
191400 127O    .    .    .    .    .    .    .    .    .    .    .    .
191430 128O    .    .    .    .    .    .    .    .    .    .    .    .
191500 129O    .    .    .    .    .    .    .    .    .    .    .    .
191530 130O    .    .    .    .    .    .    .    .    .    .    .    .
191600 131O.............................................................
191630 132O    .    .    .    .    .    .    .    .    .    .    .    .
191700 133O    .    .    .    .    .    .    .    .    .    .    .    .
191730 134O    .    .    .    .    .    .    .    .    .    .    .    .
191800 135O    .    .    .    .    .    .    .    .    .    .    .    .
191830 136O    .    .    .    .    .    .    .    .    .    .    .    .
191900 137O    .    .    .    .    .    .    .    .    .    .    .    .
191930 138O    .    .    .    .    .    .    .    .    .    .    .    .
192000 139O    .    .    .    .    .    .    .    .    .    .    .    .
192030 140O    .    .    .    .    .    .    .    .    .    .    .    .
192100 141O.............................................................
192130 142O    .    .    .    .    .    .    .    .    .    .    .    .
192200 143O    .    .    .    .    .    .    .    .    .    .    .    .
192230 144O    .    .    .    .    .    .    .    .    .    .    .    .
192300 145O    .    .    .    .    .    .    .    .    .    .    .    .
192330 146O    .    .    .    .    .    .    .    .    .    .    .    .
200000 147O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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


      **************
      *       *
 73 KK   *   ROUTE3  *
      *       *
      **************
              ROUTE COMBINED FLOW TO D OUTLET

 75 KO        OUTPUT CONTROL VARIABLES
              IPRNT         4  PRINT CONTROL
              IPLOT         0  PLOT CONTROL
              QSCAL         0.  HYDROGRAPH PLOT SCALE

         HYDROGRAPH ROUTING DATA

 76 RM        MUSKINGUM ROUTING
              NSTPS       -1 NUMBER OF SUBREACHES
              AMSKK      2.90 MUSKINGUM K
                X        .20 MUSKINGUM X

                              ***


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***
```

```
     **************
     *            *
77 KK    *   SUBD1  *
     *            *
     **************

78 KO       OUTPUT CONTROL VARIABLES
            IPRNT        4  PRINT CONTROL
            IPLOT        0  PLOT CONTROL
            QSCAL        0.  HYDROGRAPH PLOT SCALE

        SUBBASIN RUNOFF DATA

79 BA       SUBBASIN CHARACTERISTICS
            TAREA       15.88  SUBBASIN AREA

         PRECIPITATION DATA

80 PR          RECORDING STATIONS      38      43      10
81 PW                 WEIGHTS       .44     .36     .20

82 LS       SCS LOSS RATE
            STRTL       .41  INITIAL ABSTRACTION
           CRVNBR      83.00  CURVE NUMBER
            RTIMP       .00  PERCENT IMPERVIOUS AREA

83 UD       SCS DIMENSIONLESS UNITGRAPH
             TLAG      9.50  LAG

                              ***

        PRECIPITATION STATION DATA

             STATION   TOTAL   AVG. ANNUAL   WEIGHT
                 38    3.80        .00         .44
                 43  . 3.00        .00         .36
                 10     .50        .00         .20

         TEMPORAL DISTRIBUTIONS

         STATION      38,  WEIGHT =   .44
            .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
            .50    .50    .20    .20    .05    .05

         STATION      43,  WEIGHT =   .36
            .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
            .30    .30    .00    .00    .00    .00

         STATION      10,  WEIGHT =   .20
            .00    .00    .00    .00    .00    .00    .10    .10    .05    .05
            .05    .05    .05    .05    .00    .00

                                UNIT HYDROGRAPH
                              97 END-OF-PERIOD ORDINATES
        12.     25.     53.     82.    119.    157.    205.    257.    321.    389.
       466.    539.    603.    661.    705.    742.    766.    781.    785.    785.
       781.    766.    742.    715.    687.    656.    624.    586.    545.    499.
       450.    408.    368.    338.    310.    285.    261.    241.    220.    206.
       191.    176.    162.    150.    137.    125.    114.    106.     98.     90.
        82.     76.     70.     64.     59.     54.     50.     46.     42.     39.
        36.     33.     30.     28.     26.     23.     22.     20.     18.     17.
        16.     14.     13.     12.     11.     10.      9.      9.      8.      8.
         7.      7.      6.      6.      5.      5.      4.      4.      3.      3.
         3.      2.      2.      1.      1.      1.      0.
```

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

       **************
       *            *
 84 KK *    SUBD2   *
       *            *
       **************

 85 KO       OUTPUT CONTROL VARIABLES
             IPRNT        4  PRINT CONTROL
             IPLOT        0  PLOT CONTROL
             QSCAL        0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

 86 BA       SUBBASIN CHARACTERISTICS
             TAREA      14.79  SUBBASIN AREA

           PRECIPITATION DATA

 87 PR         RECORDING STATIONS      43      10
 88 PW                WEIGHTS       .55     .45

 89 LS       SCS LOSS RATE
              STRTL        .41  INITIAL ABSTRACTION
             CRVNBR      83.00  CURVE NUMBER
              RTIMP        .00  PERCENT IMPERVIOUS AREA

 90 UD       SCS DIMENSIONLESS UNITGRAPH
              TLAG       5.30  LAG

                                  ***

          PRECIPITATION STATION DATA

                 STATION   TOTAL   AVG. ANNUAL    WEIGHT
                    43    3.00        .00        .55
                    10     .50        .00        .45

           TEMPORAL DISTRIBUTIONS

           STATION      43,  WEIGHT =   .55
                .20     .20     .00     .00     .00     .00     .00     .00     .95     .95
                .30     .30     .00     .00     .00     .00     .00     .00     .00     .00
                .05     .05

           STATION      10,  WEIGHT =   .45
                .00     .00     .00     .00     .00     .00     .10     .10     .05     .05
                .05     .05     .05     .05     .00     .00     .00     .00     .00     .00
                .00     .00

                                     UNIT HYDROGRAPH
                                 55 END-OF-PERIOD ORDINATES
          35.    111.    210.    338.    503.    704.    913.   1085.   1205.   1274.
        1286.   1277.   1219.   1142.   1054.    951.    827.    693.    582.    501.
         431.    372.    327.    284.    246.    211.    181.    158.    135.    118.
         101.     87.     75.     65.     56.     48.     42.     36.     31.     27.
          23.     20.     17.     15.     13.     12.     11.      9.      8.      6.
           5.      4.      3.      2.      1.
```

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***


       **************
       *            *
  91 KK   *   SUBD3 *
       *            *
       **************

  92 KO      OUTPUT CONTROL VARIABLES
             IPRNT        4  PRINT CONTROL
             IPLOT        0  PLOT CONTROL
             QSCAL        0.  HYDROGRAPH PLOT SCALE

         SUBBASIN RUNOFF DATA

  93 BA      SUBBASIN CHARACTERISTICS
             TAREA       9.08  SUBBASIN AREA

          PRECIPITATION DATA

  94 PR        RECORDING STATIONS      38      43
  95 PW                WEIGHTS      .04     .96

  96 LS      SCS LOSS RATE
             STRTL       .41  INITIAL ABSTRACTION
            CRVNBR      83.00  CURVE NUMBER
             RTIMP       .00  PERCENT IMPERVIOUS AREA

  97 UD      SCS DIMENSIONLESS UNITGRAPH
              TLAG       5.00  LAG

                             ***

         PRECIPITATION STATION DATA

             STATION   TOTAL   AVG. ANNUAL   WEIGHT
                 38    3.80       .00        .04
                 43    3.00       .00        .96

          TEMPORAL DISTRIBUTIONS

          STATION     38,  WEIGHT =   .04
             .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
             .50    .50    .20    .20    .05    .05    .00    .00    .00    .00
             .00    .00

          STATION     43,  WEIGHT =   .96
             .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
             .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
             .05    .05

                               UNIT HYDROGRAPH
                            52 END-OF-PERIOD ORDINATES
        24.    78.   148.   240.   361.   507.   641.   743.   807.   833.
       833.   807.   756.   697.   629.   545.   453.   376.   321.   274.
       234.   205.   176.   152.   128.   110.    94.    81.    69.    59.
        50.    43.    37.    32.    27.    23.    20.    17.    15.    12.
        11.     9.     8.     7.     6.     5.     4.     4.     3.     2.
         1.     0.
```

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

      **************
      *            *
98 KK *   SUBD4    *
      *            *
      **************

99 KO       OUTPUT CONTROL VARIABLES
            IPRNT        4  PRINT CONTROL
            IPLOT        0  PLOT CONTROL
            QSCAL       0.  HYDROGRAPH PLOT SCALE

       SUBBASIN RUNOFF DATA

100 BA      SUBBASIN CHARACTERISTICS
            TAREA      18.72  SUBBASIN AREA

        PRECIPITATION DATA

101 PR         RECORDING STATIONS      43      38
102 PW                  WEIGHTS      .11     .89

103 LS      SCS LOSS RATE
            STRTL        .41  INITIAL ABSTRACTION
           CRVNBR      83.00  CURVE NUMBER
            RTIMP        .00  PERCENT IMPERVIOUS AREA

104 UD      SCS DIMENSIONLESS UNITGRAPH
            TLAG        5.70  LAG

                              ***

       PRECIPITATION STATION DATA

            STATION   TOTAL   AVG. ANNUAL   WEIGHT
                 43    3.00         .00       .11
                 38    3.80         .00       .89

        TEMPORAL DISTRIBUTIONS

        STATION     43,  WEIGHT =   .11
             .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
             .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
             .05    .05

        STATION     38,  WEIGHT =   .89
             .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
             .50    .50    .20    .20    .05    .05    .00    .00    .00    .00
             .00    .00

                              UNIT HYDROGRAPH
                           59 END-OF-PERIOD ORDINATES
      38.    118.    223.    355.    520.    727.    969.   1179.   1341.   1450.
    1509.   1519.   1506.   1435.   1349.   1253.   1142.   1011.    857.    729.
     630.    548.    477.    416.    370.    323.    283.    245.    212.    187.
     162.    142.    123.    107. .   93.     81.     71.     62.     54.     47.
      41.     36.     31.     27.     24.     21.     18.     16.     15.     13.
      12.     10.      8.      7.      6.      4.      3.      2.      1.
```

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***


      **************
      *            *
105 KK   *   COMB3  *
      *            *
      **************
              COMBINE FLOW WITH D1,D2,D3 AND D4

107 KO       OUTPUT CONTROL VARIABLES
             IPRNT         4  PRINT CONTROL
             IPLOT         0  PLOT CONTROL
             QSCAL         0.  HYDROGRAPH PLOT SCALE

108 HC       HYDROGRAPH COMBINATION
             ICOMP         5  NUMBER OF HYDROGRAPHS TO COMBINE

                                  ***


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


      **************
      *            *
109 KK   *   ROUTE4  *
      *            *
      **************
              ROUTE FLOW TO E1 AND E2 OUTLET

111 KO       OUTPUT CONTROL VARIABLES
             IPRNT         4  PRINT CONTROL
             IPLOT         0  PLOT CONTROL
             QSCAL         0.  HYDROGRAPH PLOT SCALE

         HYDROGRAPH ROUTING DATA

112 RM       MUSKINGUM ROUTING
             NSTPS       -1 NUMBER OF SUBREACHES
             AMSKK      1.50 MUSKINGUM K
               X       .20 MUSKINGUM X

                                  ***


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


      **************
      *            *
113 KK   *   SUBE1  *
      *            *
      **************

114 KO       OUTPUT CONTROL VARIABLES
             IPRNT         4  PRINT CONTROL
             IPLOT         0  PLOT CONTROL
             QSCAL         0.  HYDROGRAPH PLOT SCALE
```

```
          SUBBASIN RUNOFF DATA

 115 BA       SUBBASIN CHARACTERISTICS
              TAREA      6.35  SUBBASIN AREA

           PRECIPITATION DATA

 116 PR         RECORDING STATIONS       43
 117 PW                 WEIGHTS     1.00

 118 LS       SCS LOSS RATE
              STRTL      .44  INITIAL ABSTRACTION
             CRVNBR     82.00  CURVE NUMBER
              RTIMP      .00  PERCENT IMPERVIOUS AREA

 119 UD       SCS DIMENSIONLESS UNITGRAPH
              TLAG      1.00  LAG

                         ***

          PRECIPITATION STATION DATA

              STATION   TOTAL   AVG. ANNUAL   WEIGHT
                 43    3.00       .00       1.00

           TEMPORAL DISTRIBUTIONS

           STATION      43, WEIGHT =  1.00
               .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
               .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
               .05    .05

                                   UNIT HYDROGRAPH
                                 12 END-OF-PERIOD ORDINATES
          767.   2300.   2300.   1385.   692.   364.   190.    99.    52.    27.
           15.     5.


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


       **************
       *            *
 120 KK  *   SUBE2  *
       *            *
       **************

 121 KO       OUTPUT CONTROL VARIABLES
              IPRNT        4  PRINT CONTROL
              IPLOT        0  PLOT CONTROL
              QSCAL       0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

 122 BA       SUBBASIN CHARACTERISTICS
              TAREA     10.41  SUBBASIN AREA

           PRECIPITATION DATA

 123 PR         RECORDING STATIONS       43      38
 124 PW                 WEIGHTS      .48     .52

 125 LS       SCS LOSS RATE
```

```
               STRTL       .38  INITIAL ABSTRACTION
              CRVNBR      84.00  CURVE NUMBER
               RTIMP       .00  PERCENT IMPERVIOUS AREA

 126 UD        SCS DIMENSIONLESS UNITGRAPH
               TLAG       4.00  LAG

                               ***

          PRECIPITATION STATION DATA

               STATION   TOTAL   AVG. ANNUAL   WEIGHT
                  43   3.00      .00       .48
                  38   3.80      .00       .52

           TEMPORAL DISTRIBUTIONS

           STATION      43, WEIGHT =  .48
              .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
              .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
              .05    .05

           STATION      38, WEIGHT =  .52
              .00    .00    .20    .20    .00    .00    .00    .00    .95    .95
              .50    .50    .20    .20    .05    .05    .00    .00    .00    .00
              .00    .00

                            UNIT HYDROGRAPH
                          42 END-OF-PERIOD ORDINATES
          50.    156.    300.    500.    754.    978.   1117.   1176.   1176.   1117.
        1022.    909.    763.    607.    491.    403.    331.    280.    232.    191.
         157.    129.    108.     88.     73.     60.     49.     41.     34.     28.
          23.     19.     16.     13.     11.     10.      8.      6.      5.      3.
           2.      1.


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


        ***************
        *             *
 127 KK *   COMB4     *
        *             *
        ***************
                COMBINE FLOW WITH E1 AND E2

 129 KO        OUTPUT CONTROL VARIABLES
               IPRNT         4  PRINT CONTROL
               IPLOT         2  PLOT CONTROL
               QSCAL         0.  HYDROGRAPH PLOT SCALE

 130 HC        HYDROGRAPH COMBINATION
               ICOMP         3  NUMBER OF HYDROGRAPHS TO COMBINE

                               ***
1                            STATION    COMB4

              (O) OUTFLOW
     0.   1000.   2000.   3000.   4000.   5000.   6000.   7000.   8000.   9000.  10000.  11000.      0.
DAHRMN PER
162300  1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
162330  2O    .    .    .    .    .    .    .    .    .    .    .    .
170000  3O    .    .    .    .    .    .    .    .    .    .    .    .
```

```
170030 4O      .    .    .    .    .    .    .    .    .    .    .    .
170100 5O      .    .    .    .    .    .    .    .    .    .    .    .
170130 6O      .    .    .    .    .    .    .    .    .    .    .    .
170200 7O      .    .    .    .    .    .    .    .    .    .    .    .
170230 8O      .    .    .    .    .    .    .    .    .    .    .    .
170300 9O      .    .    .    .    .    .    .    .    .    .    .    .
170330 10. O   .    .    .    .    .    .    .    .    .    .    .    .
170400 11.......O......................................................
170430 12.     .    . O  .    .    .    .    .    .    .    .    .    .
170500 13.     .    .   O.    .    .    .    .    .    .    .    .    .
170530 14.     .    .    O    .    .    .    .    .    .    .    .    .
170600 15.     .    .   O.    .    .    .    .    .    .    .    .    .
170630 16.     .    .    .O   .    .    .    .    .    .    .    .    .
170700 17.     .    .    .  O .    .    .    .    .    .    .    .    .
170730 18.     .    .    .    . O  .    .    .    .    .    .    .    .
170800 19.     .    .    .    .    .O   .    .    .    .    .    .    .
170830 20.     .    .    .    .    .    O    .    .    .    .    .    .
170900 21..................................O..........................
170930 22.     .    .    .    .    .    .    .  O .    .    .    .    .
171000 23.     .    .    .    .    .    .    .    .  O .    .    .    .
171030 24.     .    .    .    .    .    .    .    .    .O   .    .    .
171100 25.     .    .    .    .    .    .    .    .    .  O .    .    .
171130 26.     .    .    .    .    .    .    .    .    .    O    .    .
171200 27.     .    .    .    .    .    .    .    .    .    .O   .    .
171230 28.     .    .    .    .    .    .    .    .    .    . O  .    .
171300 29.     .    .    .    .    .    .    .    .    .    .  O .    .
171330 30.     .    .    .    .    .    .    .    .    .    . O  .    .
171400 31...................................................O.........
171430 32.     .    .    .    .    .    .    .    .    .    O    .    .
171500 33.     .    .    .    .    .    .    .    .    .   O.    .    .
171530 34.     .    .    .    .    .    .    .    .    .  O .    .    .
171600 35.     .    .    .    .    .    .    .    .    . O  .    .    .
171630 36.     .    .    .    .    .    .    .    .    .O   .    .    .
171700 37.     .    .    .    .    .    .    .    .   O.    .    .    .
171730 38.     .    .    .    .    .    .    .    .  O .    .    .    .
171800 39.     .    .    .    .    .    .    .    . O  .    .    .    .
171830 40.     .    .    .    .    .    .    .    .O   .    .    .    .
171900 41.......................................O.....................
171930 42.     .    .    .    .    .    .    .  O .    .    .    .    .
172000 43.     .    .    .    .    .    .    . O  .    .    .    .    .
172030 44.     .    .    .    .    .    .    O    .    .    .    .    .
172100 45.     .    .    .    .    .    .   O.    .    .    .    .    .
172130 46.     .    .    .    .    .    . O  .    .    .    .    .    .
172200 47.     .    .    .    .    .    .O   .    .    .    .    .    .
172230 48.     .    .    .    .    .   O.    .    .    .    .    .    .
172300 49.     .    .    .    .    . O  .    .    .    .    .    .    .
172330 50.     .    .    .    .    .O   .    .    .    .    .    .    .
180000 51........................O....................................
180030 52.     .    .    .    .  O .    .    .    .    .    .    .    .
180100 53.     .    .    .    .O   .    .    .    .    .    .    .    .
180130 54.     .    .    .    O    .    .    .    .    .    .    .    .
180200 55.     .    .    .  O .    .    .    .    .    .    .    .    .
180230 56.     .    .    . O  .    .    .    .    .    .    .    .    .
180300 57.     .    .    .O   .    .    .    .    .    .    .    .    .
180330 58.     .    .    O    .    .    .    .    .    .    .    .    .
180400 59.     .    .  O .    .    .    .    .    .    .    .    .    .
180430 60.     .    . O  .    .    .    .    .    .    .    .    .    .
180500 61............O.................................................
180530 62.     .    O    .    .    .    .    .    .    .    .    .    .
180600 63.     .   O.    .    .    .    .    .    .    .    .    .    .
180630 64.     .   O.    .    .    .    .    .    .    .    .    .    .
180700 65.     .  O .    .    .    .    .    .    .    .    .    .    .
180730 66.     . O  .    .    .    .    .    .    .    .    .    .    .
180800 67.     .O   .    .    .    .    .    .    .    .    .    .    .
180830 68.     .O   .    .    .    .    .    .    .    .    .    .    .
```

```
180900 69.     O     .    .    .    .    .    .    .    .    .    .    .
180930 70.    O.     .    .    .    .    .    .    .    .    .    .    .
181000 71....O...........................................................
181030 72.   O .     .    .    .    .    .    .    .    .    .    .    .
181100 73.   O .     .    .    .    .    .    .    .    .    .    .    .
181130 74.  O  .     .    .    .    .    .    .    .    .    .    .    .
181200 75.  O  .     .    .    .    .    .    .    .    .    .    .    .
181230 76.  O  .     .    .    .    .    .    .    .    .    .    .    .
181300 77. O   .     .    .    .    .    .    .    .    .    .    .    .
181330 78. O   .     .    .    .    .    .    .    .    .    .    .    .
181400 79. O   .     .    .    .    .    .    .    .    .    .    .    .
181430 80. O   .     .    .    .    .    .    .    .    .    .    .    .
181500 81. .O............................................................
181530 82. O   .     .    .    .    .    .    .    .    .    .    .    .
181600 83. O   .     .    .    .    .    .    .    .    .    .    .    .
181630 84. O   .     .    .    .    .    .    .    .    .    .    .    .
181700 85. O   .     .    .    .    .    .    .    .    .    .    .    .
181730 86. O   .     .    .    .    .    .    .    .    .    .    .    .
181800 87.O    .     .    .    .    .    .    .    .    .    .    .    .
181830 88.O    .     .    .    .    .    .    .    .    .    .    .    .
181900 89.O    .     .    .    .    .    .    .    .    .    .    .    .
181930 90.O    .     .    .    .    .    .    .    .    .    .    .    .
182000 91.O..............................................................
182030 92.O    .     .    .    .    .    .    .    .    .    .    .    .
182100 93.O    .     .    .    .    .    .    .    .    .    .    .    .
182130 94.O    .     .    .    .    .    .    .    .    .    .    .    .
182200 95.O    .     .    .    .    .    .    .    .    .    .    .    .
182230 96.O    .     .    .    .    .    .    .    .    .    .    .    .
182300 97O     .     .    .    .    .    .    .    .    .    .    .    .
182330 98O     .     .    .    .    .    .    .    .    .    .    .    .
190000 99O     .     .    .    .    .    .    .    .    .    .    .    .
190030 100O     .     .    .    .    .    .    .    .    .    .    .    .
190100 101O..............................................................
190130 102O     .     .    .    .    .    .    .    .    .    .    .    .
190200 103O     .     .    .    .    .    .    .    .    .    .    .    .
190230 104O     .     .    .    .    .    .    .    .    .    .    .    .
190300 105O     .     .    .    .    .    .    .    .    .    .    .    .
190330 106O     .     .    .    .    .    .    .    .    .    .    .    .
190400 107O     .     .    .    .    .    .    .    .    .    .    .    .
190430 108O     .     .    .    .    .    .    .    .    .    .    .    .
190500 109O     .     .    .    .    .    .    .    .    .    .    .    .
190530 110O     .     .    .    .    .    .    .    .    .    .    .    .
190600 111O..............................................................
190630 112O     .     .    .    .    .    .    .    .    .    .    .    .
190700 113O     .     .    .    .    .    .    .    .    .    .    .    .
190730 114O     .     .    .    .    .    .    .    .    .    .    .    .
190800 115O     .     .    .    .    .    .    .    .    .    .    .    .
190830 116O     .     .    .    .    .    .    .    .    .    .    .    .
190900 117O     .     .    .    .    .    .    .    .    .    .    .    .
190930 118O     .     .    .    .    .    .    .    .    .    .    .    .
191000 119O     .     .    .    .    .    .    .    .    .    .    .    .
191030 120O     .     .    .    .    .    .    .    .    .    .    .    .
191100 121O..............................................................
191130 122O     .     .    .    .    .    .    .    .    .    .    .    .
191200 123O     .     .    .    .    .    .    .    .    .    .    .    .
191230 124O     .     .    .    .    .    .    .    .    .    .    .    .
191300 125O     .     .    .    .    .    .    .    .    .    .    .    .
191330 126O     .     .    .    .    .    .    .    .    .    .    .    .
191400 127O     .     .    .    .    .    .    .    .    .    .    .    .
191430 128O     .     .    .    .    .    .    .    .    .    .    .    .
191500 129O     .     .    .    .    .    .    .    .    .    .    .    .
191530 130O     .     .    .    .    .    .    .    .    .    .    .    .
191600 131O..............................................................
191630 132O     .     .    .    .    .    .    .    .    .    .    .    .
191700 133O     .     .    .    .    .    .    .    .    .    .    .    .
```

```
191730 134O    .    .    .    .    .    .    .    .    .    .    .    .
191800 135O    .    .    .    .    .    .    .    .    .    .    .    .
191830 136O    .    .    .    .    .    .    .    .    .    .    .    .
191900 137O    .    .    .    .    .    .    .    .    .    .    .    .
191930 138O    .    .    .    .    .    .    .    .    .    .    .    .
192000 139O    .    .    .    .    .    .    .    .    .    .    .    .
192030 140O    .    .    .    .    .    .    .    .    .    .    .    .
192100 141O............................................................
192130 142O    .    .    .    .    .    .    .    .    .    .    .    .
192200 143O    .    .    .    .    .    .    .    .    .    .    .    .
192230 144O    .    .    .    .    .    .    .    .    .    .    .    .
192300 145O    .    .    .    .    .    .    .    .    .    .    .    .
192330 146O    .    .    .    .    .    .    .    .    .    .    .    .
200000 147O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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


        **************
        *            *
131 KK  *   ROUTE5   *
        *            *
        **************
              ROUTE FLOW TO E3 AND E4 OUTLET

133 KO       OUTPUT CONTROL VARIABLES
             IPRNT          4  PRINT CONTROL
             IPLOT          0  PLOT CONTROL
             QSCAL          0.  HYDROGRAPH PLOT SCALE

          HYDROGRAPH ROUTING DATA

134 RM       MUSKINGUM ROUTING
             NSTPS       -1 NUMBER OF SUBREACHES
             AMSKK      2.10 MUSKINGUM K
               X        .20 MUSKINGUM X

                              ***


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


        **************
        *            *
135 KK  *   SUBE3    *
        *            *
        **************

136 KO       OUTPUT CONTROL VARIABLES
             IPRNT          4  PRINT CONTROL
             IPLOT          0  PLOT CONTROL
             QSCAL          0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

137 BA       SUBBASIN CHARACTERISTICS
             TAREA      18.59  SUBBASIN AREA
```

```
          PRECIPITATION DATA

138 PR        RECORDING STATIONS      43
139 PW              WEIGHTS     1.00

140 LS       SCS LOSS RATE
              STRTL       .44  INITIAL ABSTRACTION
             CRVNBR      82.00  CURVE NUMBER
              RTIMP       .00  PERCENT IMPERVIOUS AREA

141 UD        SCS DIMENSIONLESS UNITGRAPH
              TLAG      4.70  LAG

                              ***

         PRECIPITATION STATION DATA

              STATION   TOTAL   AVG. ANNUAL    WEIGHT
                 43    3.00       .00       1.00

          TEMPORAL DISTRIBUTIONS

          STATION      43,  WEIGHT =  1.00
              .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
              .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
              .05    .05

                                UNIT HYDROGRAPH
                              49 END-OF-PERIOD ORDINATES
        56.     185.    351.    574.    870.   1215.   1502.   1696.   1798.   1812.
      1784.    1672.   1541.   1390.   1201.    987.    813.    688.    581.    495.
       428.     363.    308.    258.    221.    187.    159.    134.    114.     96.
        82.      69.     59.     50.     43.     36.     31.     26.     22.     19.
        17.      15.     12.     10.      8.      6.      5.      3.      1.


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


       **************
       *            *
142 KK  *   SUBE4   *
       *            *
       **************

143 KO        OUTPUT CONTROL VARIABLES
              IPRNT        4  PRINT CONTROL
              IPLOT        0  PLOT CONTROL
              QSCAL       0.  HYDROGRAPH PLOT SCALE

         SUBBASIN RUNOFF DATA

144 BA        SUBBASIN CHARACTERISTICS
              TAREA      5.20  SUBBASIN AREA

          PRECIPITATION DATA

145 PR        RECORDING STATIONS      43
146 PW              WEIGHTS     1.00

147 LS       SCS LOSS RATE
              STRTL       .38  INITIAL ABSTRACTION
             CRVNBR      84.00  CURVE NUMBER
```

```
               RTIMP        .00  PERCENT IMPERVIOUS AREA

 148 UD        SCS DIMENSIONLESS UNITGRAPH
               TLAG       4.00  LAG

                                 ***

        PRECIPITATION STATION DATA

               STATION    TOTAL   AVG. ANNUAL    WEIGHT
                  43    3.00        .00         1.00

         TEMPORAL DISTRIBUTIONS

         STATION       43,  WEIGHT =  1.00
              .20     .20     .00     .00     .00     .00     .00     .00     .95     .95
              .30     .30     .00     .00     .00     .00     .00     .00     .00     .00
              .05     .05

                              UNIT HYDROGRAPH
                           42 END-OF-PERIOD ORDINATES
        25.     78.    150.    250.    377.    488.    558.    587.    587.    558.
       511.    454.    381.    303.    245.    201.    165.    140.    116.     95.
        79.     65.     54.     44.     36.     30.     25.     21.     17.     14.
        12.      9.      8.      6.      6.      5.      4.      3.      2.      2.
         1.      0.


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


        **************
        *            *
 149 KK *   COMB5    *
        *            *
        **************
                COMBINE FLOW WITH E3 AND E4

 151 KO        OUTPUT CONTROL VARIABLES
               IPRNT          4  PRINT CONTROL
               IPLOT          0  PLOT CONTROL
               QSCAL          0.  HYDROGRAPH PLOT SCALE

 152 HC        HYDROGRAPH COMBINATION
               ICOMP          3  NUMBER OF HYDROGRAPHS TO COMBINE

                                 ***


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


        **************
        *            *
 153 KK *   ROUTE6   *
        *            *
        **************
                ROUTE FLOW TO LW GAGE

 155 KO        OUTPUT CONTROL VARIABLES
               IPRNT          4  PRINT CONTROL
```

```
            IPLOT       0  PLOT CONTROL
            QSCAL       0.  HYDROGRAPH PLOT SCALE

        HYDROGRAPH ROUTING DATA

156 RM       MUSKINGUM ROUTING
            NSTPS      -1 NUMBER OF SUBREACHES
            AMSKK     2.20 MUSKINGUM K
              X      .20 MUSKINGUM X

                              ***


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


       **************
       *            *
157 KK *    SUBF    *
       *            *
       **************

158 KO       OUTPUT CONTROL VARIABLES
            IPRNT       4  PRINT CONTROL
            IPLOT       0  PLOT CONTROL
            QSCAL       0.  HYDROGRAPH PLOT SCALE

        SUBBASIN RUNOFF DATA

159 BA       SUBBASIN CHARACTERISTICS
            TAREA      15.36  SUBBASIN AREA

         PRECIPITATION DATA

160 PR        RECORDING STATIONS      43
161 PW               WEIGHTS     1.00

162 LS       SCS LOSS RATE
            STRTL       .47  INITIAL ABSTRACTION
           CRVNBR     81.00  CURVE NUMBER
            RTIMP       .00  PERCENT IMPERVIOUS AREA

163 UD       SCS DIMENSIONLESS UNITGRAPH
             TLAG      6.30  LAG

                              ***

        PRECIPITATION STATION DATA

             STATION   TOTAL   AVG. ANNUAL   WEIGHT
                43    3.00       .00       1.00

         TEMPORAL DISTRIBUTIONS

         STATION     43,  WEIGHT =  1.00
            .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
            .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
            .05    .05

                              UNIT HYDROGRAPH
                           65 END-OF-PERIOD ORDINATES
        26.     76.    143.    223.    326.    456.    606.    767.    906.   1008.
      1081.   1123.   1132.   1125.   1091.   1037.    976.    907.    827.    734.
```

```
     631.    545.    477.    420.    369.    326.    292.    260.    230.    204.
     178.    157.    140.    122.    109.     96.     84.     75.     65.     58.
      51.     45.     40.     35.     31.     28.     24.     22.     19.     17.
      15.     13.     12.     11.     10.      9.      8.      7.      6.      5.
       4.      3.      2.      1.      0.                                                          .


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


         **************
         *            *
164 KK   *   COMB6    *
         *            *
         **************
                COMBINE FLOW WITH F

166 KO       OUTPUT CONTROL VARIABLES
             IPRNT          3  PRINT CONTROL
             IPLOT          2  PLOT CONTROL
             QSCAL          0.  HYDROGRAPH PLOT SCALE

167 HC       HYDROGRAPH COMBINATION
             ICOMP          2  NUMBER OF HYDROGRAPHS TO COMBINE

                                   ***

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

               HYDROGRAPH AT STATION    COMB6

 PEAK FLOW     TIME                  MAXIMUM AVERAGE FLOW
                              6-HR      24-HR      72-HR    73.00-HR
+  (CFS)      (HR)
                  (CFS)
+  10811.    17.00           10508.     7728.      2866.      2827.
                 (INCHES)     .486      1.431      1.592      1.592
                  (AC-FT)     5211.     15328.     17053.     17053.

              CUMULATIVE AREA =  200.84 SQ MI

1                                   STATION    COMB6

                (O) OUTFLOW
       0.     1000.    2000.    3000.    4000.    5000.    6000.    7000.    8000.    9000.   10000.   11000.      0.
DAHRMN PER
162300  1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
162330  2O         .        .        .        .        .        .        .        .        .        .        .        .
170000  3O         .        .        .        .        .        .        .        .        .        .        .        .
170030  4O         .        .        .        .        .        .        .        .        .        .        .        .
170100  5O         .        .        .        .        .        .        .        .        .        .        .        .
170130  6O         .        .        .        .        .        .        .        .        .        .        .        .
170200  7O         .        .        .        .        .        .        .        .        .        .        .        .
170230  8O         .        .        .        .        .        .        .        .        .        .        .        .
170300  9O         .        .        .        .        .        .        .        .        .        .        .        .
170330 10O         .        .        .        .        .        .        .        .        .        .        .        .
170400 11O..........................................................................................................
170430 12.O        .        .        .        .        .        .        .        .        .        .        .        .
170500 13. O       .        .        .        .        .        .        .        .        .        .        .        .
170530 14.    O    .        .        .        .        .        .        .        .        .        .        .        .
170600 15.         O        .        .        .        .        .        .        .        .        .        .        .
170630 16.         .     O  .        .        .        .        .        .        .        .        .        .        .
170700 17.         .        .    O   .        .        .        .        .        .        .        .        .        .
```

```
170730 18.    .    .    . O  .    .    .    .    .    .    .    .    .
170800 19.    .    .    .    . O  .    .    .    .    .    .    .    .
170830 20.    .    .    .    .    O    .    .    .    .    .    .    .
170900 21............................O...............................
170930 22.    .    .    .    .    .    . O  .    .    .    .    .    .
171000 23.    .    .    .    .    .    .    O    .    .    .    .    .
171030 24.    .    .    .    .    .    .    .  O .    .    .    .    .
171100 25.    .    .    .    .    .    .    .    .O   .    .    .    .
171130 26.    .    .    .    .    .    .    .    .  O .    .    .    .
171200 27.    .    .    .    .    .    .    .    .    O    .    .    .
171230 28.    .    .    .    .    .    .    .    .    . O  .    .    .
171300 29.    .    .    .    .    .    .    .    .    .  O .    .    .
171330 30.    .    .    .    .    .    .    .    .    .    O    .    .
171400 31...................................................O........
171430 32.    .    .    .    .    .    .    .    .    .    . O  .    .
171500 33.    .    .    .    .    .    .    .    .    .    .  O .    .
171530 34.    .    .    .    .    .    .    .    .    .    .   O.    .
171600 35.    .    .    .    .    .    .    .    .    .    .   O.    .
171630 36.    .    .    .    .    .    .    .    .    .    .   O.    .
171700 37.    .    .    .    .    .    .    .    .    .    .  O .    .
171730 38.    .    .    .    .    .    .    .    .    .    .  O .    .
171800 39.    .    .    .    .    .    .    .    .    .    .  O .    .
171830 40.    .    .    .    .    .    .    .    .    .    . O  .    .
171900 41..................................................O.........
171930 42.    .    .    .    .    .    .    .    .    .   O.    .    .
172000 43.    .    .    .    .    .    .    .    .    .  O .    .    .
172030 44.    .    .    .    .    .    .    .    .    . O  .    .    .
172100 45.    .    .    .    .    .    .    .    .    .O   .    .    .
172130 46.    .    .    .    .    .    .    .    .   O.    .    .    .
172200 47.    .    .    .    .    .    .    .    .  O .    .    .    .
172230 48.    .    .    .    .    .    .    .    . O  .    .    .    .
172300 49.    .    .    .    .    .    .    .    .O   .    .    .    .
172330 50.    .    .    .    .    .    .    .  O .    .    .    .    .
180000 51.....................................O......................
180030 52.    .    .    .    .    .    .    .O   .    .    .    .    .
180100 53.    .    .    .    .    .    .   O.    .    .    .    .    .
180130 54.    .    .    .    .    .    .  O .    .    .    .    .    .
180200 55.    .    .    .    .    .    . O  .    .    .    .    .    .
180230 56.    .    .    .    .    .    O    .    .    .    .    .    .
180300 57.    .    .    .    .    .  O .    .    .    .    .    .    .
180330 58.    .    .    .    .    . O  .    .    .    .    .    .    .
180400 59.    .    .    .    .    O    .    .    .    .    .    .    .
180430 60.    .    .    .    .  O .    .    .    .    .    .    .    .
180500 61......................O.....................................
180530 62.    .    .    .    .O   .    .    .    .    .    .    .    .
180600 63.    .    .    .   O.    .    .    .    .    .    .    .    .
180630 64.    .    .    .  O .    .    .    .    .    .    .    .    .
180700 65.    .    .    . O  .    .    .    .    .    .    .    .    .
180730 66.    .    .    .O   .    .    .    .    .    .    .    .    .
180800 67.    .    .   O.    .    .    .    .    .    .    .    .    .
180830 68.    .    .  O .    .    .    .    .    .    .    .    .    .
180900 69.    .    . O  .    .    .    .    .    .    .    .    .    .
180930 70.    .    .O   .    .    .    .    .    .    .    .    .    .
181000 71..........O.................................................
181030 72.    .   O.    .    .    .    .    .    .    .    .    .    .
181100 73.    .  O .    .    .    .    .    .    .    .    .    .    .
181130 74.    .  O .    .    .    .    .    .    .    .    .    .    .
181200 75.    . O  .    .    .    .    .    .    .    .    .    .    .
181230 76.    . O  .    .    .    .    .    .    .    .    .    .    .
181300 77.    .O   .    .    .    .    .    .    .    .    .    .    .
181330 78.    .O   .    .    .    .    .    .    .    .    .    .    .
181400 79.    O    .    .    .    .    .    .    .    .    .    .    .
181430 80.   O.    .    .    .    .    .    .    .    .    .    .    .
181500 81...O........................................................
181530 82.  O .    .    .    .    .    .    .    .    .    .    .    .
```

```
181600 83.    O .    .    .    .    .    .    .    .    .    .    .    .
181630 84.   O  .    .    .    .    .    .    .    .    .    .    .    .
181700 85.  O   .    .    .    .    .    .    .    .    .    .    .    .
181730 86.  O   .    .    .    .    .    .    .    .    .    .    .    .
181800 87. O    .    .    .    .    .    .    .    .    .    .    .    .
181830 88. O    .    .    .    .    .    .    .    .    .    .    .    .
181900 89. O    .    .    .    .    .    .    .    .    .    .    .    .
181930 90. O    .    .    .    .    .    .    .    .    .    .    .    .
182000 91. .O...........................................................
182030 92. O    .    .    .    .    .    .    .    .    .    .    .    .
182100 93. O    .    .    .    .    .    .    .    .    .    .    .    .
182130 94. O    .    .    .    .    .    .    .    .    .    .    .    .
182200 95. O    .    .    .    .    .    .    .    .    .    .    .    .
182230 96. O    .    .    .    .    .    .    .    .    .    .    .    .
182300 97.O     .    .    .    .    .    .    .    .    .    .    .    .
182330 98.O     .    .    .    .    .    .    .    .    .    .    .    .
190000 99.O     .    .    .    .    .    .    .    .    .    .    .    .
190030 100.O    .    .    .    .    .    .    .    .    .    .    .    .
190100 101.O........................................................
190130 102.O    .    .    .    .    .    .    .    .    .    .    .    .
190200 103.O    .    .    .    .    .    .    .    .    .    .    .    .
190230 104.O    .    .    .    .    .    .    .    .    .    .    .    .
190300 105.O    .    .    .    .    .    .    .    .    .    .    .    .
190330 106.O    .    .    .    .    .    .    .    .    .    .    .    .
190400 107O     .    .    .    .    .    .    .    .    .    .    .    .
190430 108O     .    .    .    .    .    .    .    .    .    .    .    .
190500 109O     .    .    .    .    .    .    .    .    .    .    .    .
190530 110O     .    .    .    .    .    .    .    .    .    .    .    .
190600 111O.........................................................
190630 112O     .    .    .    .    .    .    .    .    .    .    .    .
190700 113O     .    .    .    .    .    .    .    .    .    .    .    .
190730 114O     .    .    .    .    .    .    .    .    .    .    .    .
190800 115O     .    .    .    .    .    .    .    .    .    .    .    .
190830 116O     .    .    .    .    .    .    .    .    .    .    .    .
190900 117O     .    .    .    .    .    .    .    .    .    .    .    .
190930 118O     .    .    .    .    .    .    .    .    .    .    .    .
191000 119O     .    .    .    .    .    .    .    .    .    .    .    .
191030 120O     .    .    .    .    .    .    .    .    .    .    .    .
191100 121O.........................................................
191130 122O     .    .    .    .    .    .    .    .    .    .    .    .
191200 123O     .    .    .    .    .    .    .    .    .    .    .    .
191230 124O     .    .    .    .    .    .    .    .    .    .    .    .
191300 125O     .    .    .    .    .    .    .    .    .    .    .    .
191330 126O     .    .    .    .    .    .    .    .    .    .    .    .
191400 127O     .    .    .    .    .    .    .    .    .    .    .    .
191430 128O     .    .    .    .    .    .    .    .    .    .    .    .
191500 129O     .    .    .    .    .    .    .    .    .    .    .    .
191530 130O     .    .    .    .    .    .    .    .    .    .    .    .
191600 131O.........................................................
191630 132O     .    .    .    .    .    .    .    .    .    .    .    .
191700 133O     .    .    .    .    .    .    .    .    .    .    .    .
191730 134O     .    .    .    .    .    .    .    .    .    .    .    .
191800 135O     .    .    .    .    .    .    .    .    .    .    .    .
191830 136O     .    .    .    .    .    .    .    .    .    .    .    .
191900 137O     .    .    .    .    .    .    .    .    .    .    .    .
191930 138O     .    .    .    .    .    .    .    .    .    .    .    .
192000 139O     .    .    .    .    .    .    .    .    .    .    .    .
192030 140O     .    .    .    .    .    .    .    .    .    .    .    .
192100 141O.........................................................
192130 142O     .    .    .    .    .    .    .    .    .    .    .    .
192200 143O     .    .    .    .    .    .    .    .    .    .    .    .
192230 144O     .    .    .    .    .    .    .    .    .    .    .    .
192300 145O     .    .    .    .    .    .    .    .    .    .    .    .
192330 146O     .    .    .    .    .    .    .    .    .    .    .    .
200000 147O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
```

```
1

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


      **************
      *            *
168 KK   *   COMP1  *
      *            *
      **************

169 KO       OUTPUT CONTROL VARIABLES
             IPRNT        1  PRINT CONTROL
             IPLOT        0  PLOT CONTROL
             QSCAL        0.  HYDROGRAPH PLOT SCALE
               Compare actual to computed hydrograph @ LW

171 IN       TIME DATA FOR INPUT TIME SERIES
             JXMIN       180  TIME INTERVAL IN MINUTES
             JXDATE    17JUL93  STARTING DATE
             JXTIME        0  STARTING TIME

                               ***



******************************************************************************************************************
*****
  *                                                                    *
  *                   COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS                *
  *                                                                    *

******************************************************************************************************************
*****
  *                                                                    *
  *                                     TIME TO     LAG                      *
  *                 SUM OF     EQUIV      MEAN     CENTER    C.M. TO     PEAK     TIME OF   *
  *                 FLOWS      DEPTH      FLOW     OF MASS    C.M.       FLOW      PEAK    *
  *                                                                    *
  *   COMPUTED HYDROGRAPH     412678.    1.592      2807.    21.28     21.28     10811.    17.00    *
  *   OBSERVED HYDROGRAPH     396119.    1.528      2695.    23.26     23.26     10753.    16.00    *
  *                                                                    *
  *   DIFFERENCE           16559.    .064      113.    -1.98     -1.98       58.    1.00    *
  *   PERCENT DIFFERENCE        4.18                                 -8.49       .54          *
  *                                                                    *
  *             STANDARD ERROR    942.           AVERAGE ABSOLUTE ERROR     680.           *
  *           OBJECTIVE FUNCTION    1138.      AVERAGE PERCENT ABSOLUTE ERROR    55.86          *
  *                                                                    *

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


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

                          HYDROGRAPH AT STATION    COMP1

******************************************************************************************************************
****************
```

```
                              *                          *
 DA MON HRMN ORD   COMP Q   OBS Q  RESIDUL * DA MON HRMN ORD   COMP Q   OBS Q  RESIDUL * DA MON HRMN
ORD   COMP Q   OBS Q  RESIDUL
                              *                          *
 16 JUL 2300  1     0.     0.      0. * 17 JUL 2330  50   7783.  6052.   1731. * 19 JUL 0000  99    118.   575.  -457.
 16 JUL 2330  2     0.     0.      0. * 18 JUL 0000  51   7490.  5769.   1721. * 19 JUL 0030 100    106.   534.  -428.
 17 JUL 0000  3     0.     0.      0. * 18 JUL 0030  52   7192.  5600.   1592. * 19 JUL 0100 101     94.   492.  -398.
 17 JUL 0030  4     0.     0.      0. * 18 JUL 0100  53   6890.  5431.   1458. * 19 JUL 0130 102     84.   451.  -367.
 17 JUL 0100  5     0.     0.      0. * 18 JUL 0130  54   6584.  5263.   1321. * 19 JUL 0200 103     75.   410.  -335.
 17 JUL 0130  6     0.     0.      0. * 18 JUL 0200  55   6276.  5094.   1182. * 19 JUL 0230 104     66.   368.  -302.
 17 JUL 0200  7     0.     0.      0. * 18 JUL 0230  56   5966.  4925.   1042. * 19 JUL 0300 105     59.   327.  -268.
 17 JUL 0230  8     0.     0.      0. * 18 JUL 0300  57   5657.  4756.    901. * 19 JUL 0330 106     52.   285.  -233.
 17 JUL 0300  9     0.     0.      0. * 18 JUL 0330  58   5350.  4607.    743. * 19 JUL 0400 107     46.   243.  -197.
 17 JUL 0330 10     6.   393.   -387. * 18 JUL 0400  59   5047.  4459.    588. * 19 JUL 0430 108     40.   201.  -161.
 17 JUL 0400 11    26.   787.   -761. * 18 JUL 0430  60   4747.  4310.    437. * 19 JUL 0500 109     36.   159.  -123.
 17 JUL 0430 12    61.  1180.  -1119. * 18 JUL 0500  61   4454.  4161.    293. * 19 JUL 0530 110     31.   117.   -86.
 17 JUL 0500 13   181.  1573.  -1392. * 18 JUL 0530  62   4169.  4013.    157. * 19 JUL 0600 111     27.    75.   -48.
 17 JUL 0530 14   500.  1967.  -1466. * 18 JUL 0600  63   3893.  3864.     29. * 19 JUL 0630 112     24.    75.   -51.
 17 JUL 0600 15  1036.  2360.  -1324. * 18 JUL 0630  64   3626.  3739.   -113. * 19 JUL 0700 113     21.    75.   -54.
 17 JUL 0630 16  1750.  2647.   -896. * 18 JUL 0700  65   3370.  3615.   -244. * 19 JUL 0730 114     18.    75.   -57.
 17 JUL 0700 17  2572.  2933.   -361. * 18 JUL 0730  66   3125.  3490.   -365. * 19 JUL 0800 115     15.    75.   -60.
 17 JUL 0730 18  3427.  3220.    207. * 18 JUL 0800  67   2892.  3365.   -474. * 19 JUL 0830 116     13.    75.   -62.
 17 JUL 0800 19  4261.  3506.    755. * 18 JUL 0830  68   2670.  3241.   -571. * 19 JUL 0900 117     11.    75.   -64.
 17 JUL 0830 20  5044.  3793.   1251. * 18 JUL 0900  69   2459.  3116.   -657. * 19 JUL 0930 118     10.    75.   -65.
 17 JUL 0900 21  5767.  4079.   1688. * 18 JUL 0930  70   2261.  2992.   -731. * 19 JUL 1000 119      8.    75.   -67.
 17 JUL 0930 22  6430.  4469.   1961. * 18 JUL 1000  71   2074.  2869.   -794. * 19 JUL 1030 120      7.    75.   -68.
 17 JUL 1000 23  7035.  4860.   2175. * 18 JUL 1030  72   1900.  2745.   -845. * 19 JUL 1100 121      6.    75.   -69.
 17 JUL 1030 24  7591.  5250.   2341. * 18 JUL 1100  73   1736.  2621.   -885. * 19 JUL 1130 122      5.    75.   -70.
 17 JUL 1100 25  8100.  5640.   2459. * 18 JUL 1130  74   1584.  2498.   -914. * 19 JUL 1200 123      4.    75.   -71.
 17 JUL 1130 26  8572.  6031.   2542. * 18 JUL 1200  75   1443.  2374.   -931. * 19 JUL 1230 124      3.    75.   -72.
 17 JUL 1200 27  9004.  6421.   2583. * 18 JUL 1230  76   1312.  2296.   -984. * 19 JUL 1300 125      3.    75.   -72.
 17 JUL 1230 28  9393.  7143.   2250. * 18 JUL 1300  77   1192.  2218.  -1026. * 19 JUL 1330 126      2.    75.   -73.
 17 JUL 1300 29  9741.  7865.   1876. * 18 JUL 1330  78   1081.  2140.  -1059. * 19 JUL 1400 127      2.    75.   -73.
 17 JUL 1330 30 10040.  8587.   1453. * 18 JUL 1400  79    980.  2062.  -1082. * 19 JUL 1430 128      2.    75.   -73.
 17 JUL 1400 31 10289.  9309.    980. * 18 JUL 1430  80    887.  1984.  -1097. * 19 JUL 1500 129      1.    75.   -74.
 17 JUL 1430 32 10495. 10031.    464. * 18 JUL 1500  81    802.  1906.  -1104. * 19 JUL 1530 130      1.    75.   -74.
 17 JUL 1500 33 10655. 10753.    -98. * 18 JUL 1530  82    725.  1824.  -1099. * 19 JUL 1600 131      1.    75.   -74.
 17 JUL 1530 34 10762. 10534.    228. * 18 JUL 1600  83    654.  1742.  -1088. * 19 JUL 1630 132      1.    75.   -74.
 17 JUL 1600 35 10811. 10314.    497. * 18 JUL 1630  84    590.  1661.  -1070. * 19 JUL 1700 133      1.    75.   -74.
 17 JUL 1630 36 10806. 10095.    711. * 18 JUL 1700  85    532.  1579.  -1046. * 19 JUL 1730 134      1.    75.   -74.
 17 JUL 1700 37 10748.  9876.    872. * 18 JUL 1730  86    480.  1497.  -1017. * 19 JUL 1800 135      0.    75.   -75.
 17 JUL 1730 38 10642.  9656.    986. * 18 JUL 1800  87    432.  1415.   -983. * 19 JUL 1830 136      0.    75.   -75.
 17 JUL 1800 39 10496.  9437.   1059. * 18 JUL 1830  88    389.  1330.   -941. * 19 JUL 1900 137      0.    75.   -75.
 17 JUL 1830 40 10317.  9109.   1208. * 18 JUL 1900  89    350.  1245.   -895. * 19 JUL 1930 138      0.    75.   -75.
 17 JUL 1900 41 10112.  8781.   1332. * 18 JUL 1930  90    315.  1161.   -846. * 19 JUL 2000 139      0.    75.   -75.
 17 JUL 1930 42  9890.  8453.   1438. * 18 JUL 2000  91    283.  1076.   -793. * 19 JUL 2030 140      0.    75.   -75.
 17 JUL 2000 43  9654.  8124.   1530. * 18 JUL 2030  92    254.   991.   -736. * 19 JUL 2100 141      0.    75.   -75.
 17 JUL 2030 44  9409.  7796.   1613. * 18 JUL 2100  93    228.   906.   -678. * 19 JUL 2130 142      0.    75.   -75.
 17 JUL 2100 45  9156.  7468.   1688. * 18 JUL 2130  94    205.   851.   -646. * 19 JUL 2200 143      0.    75.   -75.
 17 JUL 2130 46  8895.  7185.   1710. * 18 JUL 2200  95    184.   796.   -612. * 19 JUL 2230 144      0.    75.   -75.
 17 JUL 2200 47  8627.  6902.   1725. * 18 JUL 2230  96    165.   741.   -576. * 19 JUL 2300 145      0.    75.   -75.
 17 JUL 2230 48  8352.  6619.   1733. * 18 JUL 2300  97    148.   685.   -538. * 19 JUL 2330 146      0.    75.   -75.
 17 JUL 2300 49  8070.  6335.   1735. * 18 JUL 2330  98    132.   630.   -498. * 20 JUL 0000 147      0.    75.   -75.
                              *                          *

************************************************************************************************************************
****************
1                                  STATION   COMP1

                   (I) INFLOW,  (O) OUTFLOW,  (*) OBSERVED FLOW
      0.   2000.   4000.   6000.   8000.   10000.   12000.     0.      0.      0.      0.      0.      0.
 DAHRMN PER
 162300  1I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
 162330  2I         .         .         .         .         .         .         .         .         .         .         .         .
 170000  3I         .         .         .         .         .         .         .         .         .         .         .         .
```

```
170030  4I    .    .    .    .    .    .    .    .    .    .    .    .
170100  5I    .    .    .    .    .    .    .    .    .    .    .    .
170130  6I    .    .    .    .    .    .    .    .    .    .    .    .
170200  7I    .    .    .    .    .    .    .    .    .    .    .    .
170230  8I    .    .    .    .    .    .    .    .    .    .    .    .
170300  9I    .    .    .    .    .    .    .    .    .    .    .    .
170330 10I*   .    .    .    .    .    .    .    .    .    .    .    .
170400 11I.*..........................................................
170430 12I  * .    .    .    .    .    .    .    .    .    .    .    .
170500 13IO  *.    .    .    .    .    .    .    .    .    .    .    .
170530 14I O  *    .    .    .    .    .    .    .    .    .    .    .
170600 15I  O .*   .    .    .    .    .    .    .    .    .    .    .
170630 16I   O. *  .    .    .    .    .    .    .    .    .    .    .
170700 17I    . O *.    .    .    .    .    .    .    .    .    .    .
170730 18I    .  *O.    .    .    .    .    .    .    .    .    .    .
170800 19I    .   *.O   .    .    .    .    .    .    .    .    .    .
170830 20I    .   *.  O .    .    .    .    .    .    .    .    .    .
170900 21I.........*....O.............................................
170930 22I    .    .*   .O   .    .    .    .    .    .    .    .    .
171000 23I    .    . *  . O  .    .    .    .    .    .    .    .    .
171030 24I    .    .  * .   O.    .    .    .    .    .    .    .    .
171100 25I    .    .   *.    O    .    .    .    .    .    .    .    .
171130 26I    .    .    *    .O   .    .    .    .    .    .    .    .
171200 27I    .    .    .*   . O  .    .    .    .    .    .    .    .
171230 28I    .    .    .  * .  O .    .    .    .    .    .    .    .
171300 29I    .    .    .   *.   O.    .    .    .    .    .    .    .
171330 30I    .    .    .    .*   O    .    .    .    .    .    .    .
171400 31I......................*.O...................................
171430 32I    .    .    .    .    *O   .    .    .    .    .    .    .
171500 33I    .    .    .    .    .O*  .    .    .    .    .    .    .
171530 34I    .    .    .    .    .*O  .    .    .    .    .    .    .
171600 35I    .    .    .    .    .*O  .    .    .    .    .    .    .
171630 36I    .    .    .    .    * O  .    .    .    .    .    .    .
171700 37I    .    .    .    .    *. O .    .    .    .    .    .    .
171730 38I    .    .    .    .   *. O  .    .    .    .    .    .    .
171800 39I    .    .    .    .  * .O   .    .    .    .    .    .    .
171830 40I    .    .    .    . *  .O   .    .    .    .    .    .    .
171900 41I.....................*...O..................................
171930 42I    .    .    .    .*   O    .    .    .    .    .    .    .
172000 43I    .    .    .    .*  O.    .    .    .    .    .    .    .
172030 44I    .    .    .    *.  O.    .    .    .    .    .    .    .
172100 45I    .    .    .   *.  O .    .    .    .    .    .    .    .
172130 46I    .    .    .  * . O  .    .    .    .    .    .    .    .
172200 47I    .    .    .  * .O   .    .    .    .    .    .    .    .
172230 48I    .    .    . *  .O   .    .    .    .    .    .    .    .
172300 49I    .    .    .*   O    .    .    .    .    .    .    .    .
172330 50I    .    .    *   O.    .    .    .    .    .    .    .    .
180000 51I..............*...O.........................................
180030 52I    .    .   *.   O.    .    .    .    .    .    .    .    .
180100 53I    .    .  * .  O .    .    .    .    .    .    .    .    .
180130 54I    .    .  * . O  .    .    .    .    .    .    .    .    .
180200 55I    .    .  * .O   .    .    .    .    .    .    .    .    .
180230 56I    .    .  * O    .    .    .    .    .    .    .    .    .
180300 57I    .    . * O.    .    .    .    .    .    .    .    .    .
180330 58I    .    . * O.    .    .    .    .    .    .    .    .    .
180400 59I    .    .* O .    .    .    .    .    .    .    .    .    .
180430 60I    .    .*O  .    .    .    .    .    .    .    .    .    .
180500 61I..........*O................................................
180530 62I    .    *O   .    .    .    .    .    .    .    .    .    .
180600 63I    .    *.   .    .    .    .    .    .    .    .    .    .
180630 64I    .   O*.   .    .    .    .    .    .    .    .    .    .
180700 65I    .   O* .  .    .    .    .    .    .    .    .    .    .
180730 66I    .  O*.    .    .    .    .    .    .    .    .    .    .
180800 67I    . O *.    .    .    .    .    .    .    .    .    .    .
180830 68I    .O * .    .    .    .    .    .    .    .    .    .    .
```

```
180900 69I    .O  * .    .    .    .    .    .    .    .    .    .    .
180930 70I    .O  * .    .    .    .    .    .    .    .    .    .    .
181000 71I....O.*......................................................
181030 72I    O. *  .    .    .    .    .    .    .    .    .    .    .
181100 73I    O. *  .    .    .    .    .    .    .    .    .    .    .
181130 74I   O .*   .    .    .    .    .    .    .    .    .    .    .
181200 75I   O .*   .    .    .    .    .    .    .    .    .    .    .
181230 76I   O .*   .    .    .    .    .    .    .    .    .    .    .
181300 77I  O  .*   .    .    .    .    .    .    .    .    .    .    .
181330 78I O   .*   .    .    .    .    .    .    .    .    .    .    .
181400 79I  O  *    .    .    .    .    .    .    .    .    .    .    .
181430 80I O   *    .    .    .    .    .    .    .    .    .    .    .
181500 81I.O..*........................................................
181530 82I O  *.    .    .    .    .    .    .    .    .    .    .    .
181600 83I O  *.    .    .    .    .    .    .    .    .    .    .    .
181630 84I O  *.    .    .    .    .    .    .    .    .    .    .    .
181700 85I O  *.    .    .    .    .    .    .    .    .    .    .    .
181730 86I O * .    .    .    .    .    .    .    .    .    .    .    .
181800 87I O * .    .    .    .    .    .    .    .    .    .    .    .
181830 88I O * .    .    .    .    .    .    .    .    .    .    .    .
181900 89I O * .    .    .    .    .    .    .    .    .    .    .    .
181930 90I O * .    .    .    .    .    .    .    .    .    .    .    .
182000 91IO..*.........................................................
182030 92IO *  .    .    .    .    .    .    .    .    .    .    .    .
182100 93IO *  .    .    .    .    .    .    .    .    .    .    .    .
182130 94IO *  .    .    .    .    .    .    .    .    .    .    .    .
182200 95IO *  .    .    .    .    .    .    .    .    .    .    .    .
182230 96IO *  .    .    .    .    .    .    .    .    .    .    .    .
182300 97IO *  .    .    .    .    .    .    .    .    .    .    .    .
182330 98IO *  .    .    .    .    .    .    .    .    .    .    .    .
190000 99IO *  .    .    .    .    .    .    .    .    .    .    .    .
190030 100IO *  .    .    .    .    .    .    .    .    .    .    .    .
190100 101I *...........................................................
190130 102I *   .    .    .    .    .    .    .    .    .    .    .    .
190200 103I *   .    .    .    .    .    .    .    .    .    .    .    .
190230 104I *   .    .    .    .    .    .    .    .    .    .    .    .
190300 105I *   .    .    .    .    .    .    .    .    .    .    .    .
190330 106I*    .    .    .    .    .    .    .    .    .    .    .    .
190400 107I*    .    .    .    .    .    .    .    .    .    .    .    .
190430 108I*    .    .    .    .    .    .    .    .    .    .    .    .
190500 109I*    .    .    .    .    .    .    .    .    .    .    .    .
190530 110I*    .    .    .    .    .    .    .    .    .    .    .    .
190600 111I.............................................................
190630 112I     .    .    .    .    .    .    .    .    .    .    .    .
190700 113I     .    .    .    .    .    .    .    .    .    .    .    .
190730 114I     .    .    .    .    .    .    .    .    .    .    .    .
190800 115I     .    .    .    .    .    .    .    .    .    .    .    .
190830 116I     .    .    .    .    .    .    .    .    .    .    .    .
190900 117I     .    .    .    .    .    .    .    .    .    .    .    .
190930 118I     .    .    .    .    .    .    .    .    .    .    .    .
191000 119I     .    .    .    .    .    .    .    .    .    .    .    .
191030 120I     .    .    .    .    .    .    .    .    .    .    .    .
191100 121I.............................................................
191130 122I     .    .    .    .    .    .    .    .    .    .    .    .
191200 123I     .    .    .    .    .    .    .    .    .    .    .    .
191230 124I     .    .    .    .    .    .    .    .    .    .    .    .
191300 125I     .    .    .    .    .    .    .    .    .    .    .    .
191330 126I     .    .    .    .    .    .    .    .    .    .    .    .
191400 127I     .    .    .    .    .    .    .    .    .    .    .    .
191430 128I     .    .    .    .    .    .    .    .    .    .    .    .
191500 129I     .    .    .    .    .    .    .    .    .    .    .    .
191530 130I     .    .    .    .    .    .    .    .    .    .    .    .
191600 131I.............................................................
191630 132I     .    .    .    .    .    .    .    .    .    .    .    .
191700 133I     .    .    .    .    .    .    .    .    .    .    .    .
```

```
191730 134I    .    .    .    .    .    .    .    .    .    .    .    .
191800 135I    .    .    .    .    .    .    .    .    .    .    .    .
191830 136I    .    .    .    .    .    .    .    .    .    .    .    .
191900 137I    .    .    .    .    .    .    .    .    .    .    .    .
191930 138I    .    .    .    .    .    .    .    .    .    .    .    .
192000 139I    .    .    .    .    .    .    .    .    .    .    .    .
192030 140I    .    .    .    .    .    .    .    .    .    .    .    .
192100 141I.............................................................
192130 142I    .    .    .    .    .    .    .    .    .    .    .    .
192200 143I    .    .    .    .    .    .    .    .    .    .    .    .
192230 144I    .    .    .    .    .    .    .    .    .    .    .    .
192300 145I    .    .    .    .    .    .    .    .    .    .    .    .
192330 146I    .    .    .    .    .    .    .    .    .    .    .    .
200000 147I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1


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


        **************
        *            *
 174 KK *   ROUTE7   *
        *            *
        **************
              ROUTE FLOW TO SKUNK RIVER

 176 KO       OUTPUT CONTROL VARIABLES
              IPRNT         4  PRINT CONTROL
              IPLOT         0  PLOT CONTROL
              QSCAL         0.  HYDROGRAPH PLOT SCALE

          HYDROGRAPH ROUTING DATA

 177 RM       MUSKINGUM ROUTING
              NSTPS       -1 NUMBER OF SUBREACHES
              AMSKK      1.20 MUSKINGUM K
                 X        .20 MUSKINGUM X

                              ***


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


        **************
        *            *
 178 KK *    SUBG    *
        *            *
        **************

 179 KO       OUTPUT CONTROL VARIABLES
              IPRNT         4  PRINT CONTROL
              IPLOT         0  PLOT CONTROL
              QSCAL         0.  HYDROGRAPH PLOT SCALE

          SUBBASIN RUNOFF DATA

 180 BA       SUBBASIN CHARACTERISTICS
              TAREA      16.62  SUBBASIN AREA
```

```
          PRECIPITATION DATA

181 PR        RECORDING STATIONS     43
182 PW              WEIGHTS    1.00

183 LS      SCS LOSS RATE
             STRTL       .47  INITIAL ABSTRACTION
            CRVNBR      81.00  CURVE NUMBER
             RTIMP       .00  PERCENT IMPERVIOUS AREA

184 UD       SCS DIMENSIONLESS UNITGRAPH
             TLAG       5.20  LAG

                               ***

         PRECIPITATION STATION DATA

             STATION   TOTAL   AVG. ANNUAL   WEIGHT
                43    3.00        .00        1.00

          TEMPORAL DISTRIBUTIONS

          STATION      43,  WEIGHT =  1.00
              .20    .20    .00    .00    .00    .00    .00    .00    .95    .95
              .30    .30    .00    .00    .00    .00    .00    .00    .00    .00
              .05    .05

                              UNIT HYDROGRAPH
                           54 END-OF-PERIOD ORDINATES
        41.    130.    247.    398.    595.    833.   1072.   1263.   1393.   1461.
      1472.   1457.   1376.   1283.   1177.   1049.    896.    749.    633.    544.
       466.    403.    353.    304.    264.    223.    194.    167.    144.    124.
       106.     91.     78.     68.     58.     51.     43.     38.     32.     28.
        24.     21.     18.     16.     14.     12.     11.      9.      7.      6.
         5.      3.      2.      1.


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


       **************
       *            *
185 KK *    COMB7   *
       *            *
       **************
              COMBINE FLOW WITH G

187 KO      OUTPUT CONTROL VARIABLES
            IPRNT        4  PRINT CONTROL
            IPLOT        0  PLOT CONTROL
            QSCAL       0.  HYDROGRAPH PLOT SCALE

188 HC      HYDROGRAPH COMBINATION
            ICOMP        2  NUMBER OF HYDROGRAPHS TO COMBINE

                               ***
1
                                 RUNOFF SUMMARY
                            FLOW IN CUBIC FEET PER SECOND
                          TIME IN HOURS,  AREA IN SQUARE MILES

                      PEAK   TIME OF   AVERAGE FLOW FOR MAXIMUM PERIOD     BASIN    MAXIMUM    TIME OF
    OPERATION      STATION     FLOW     PEAK                               AREA     STAGE    MAX STAGE
```

```
+                            6-HOUR   24-HOUR   72-HOUR

      HYDROGRAPH AT
+                SUBA    2073.  15.00     1847.     817.     275.    17.91

      ROUTED TO
+              ROUTE1    1961.  16.50     1769.     815.     275.    17.91

      HYDROGRAPH AT
+               SUBB1    1096.  13.50     1008.     493.     169.    18.10

      HYDROGRAPH AT
+               SUBB2    2751.  13.50     2518.    1211.     411.    20.66

      3 COMBINED AT
+               COMB1    5382.  15.00     4972.    2510.     855.    56.67

      ROUTED TO
+              ROUTE2    4860.  17.50     4547.    2484.     855.    56.67

      HYDROGRAPH AT
+               SUBC1    2712.  10.50     2252.     832.     278.    15.62

      HYDROGRAPH AT
+               SUBC2    2537.  10.50     2132.     804.     268.    14.17

      3 COMBINED AT
+               COMB2    6815.  12.00     6495.    4061.    1401.    86.46

      ROUTED TO
+              ROUTE3    6177.  16.50     6074.    4000.    1401.    86.46

      HYDROGRAPH AT
+               SUBD1    1024.  15.00      968.     539.     190.    15.88

      HYDROGRAPH AT
+               SUBD2     723.  10.50      613.     241.      81.    14.79

      HYDROGRAPH AT
+               SUBD3    1143.  10.00      949.     359.     120.     9.08

      HYDROGRAPH AT
+               SUBD4    2971.  11.00     2558.    1020.     341.    18.72

      5 COMBINED AT
+               COMB3   10277.  13.00     9656.    6076.    2132.   144.93

      ROUTED TO
+              ROUTE4    9919.  14.50     9417.    6045.    2132.   144.93

      HYDROGRAPH AT
+               SUBE1    2396.   6.00      886.     235.      78.     6.35

      HYDROGRAPH AT
+               SUBE2    2015.   9.00     1557.     521.     174.    10.41

      3 COMBINED AT
+               COMB4   10456.  14.00     9948.    6603.    2385.   161.69

      ROUTED TO
+              ROUTE5    9957.  16.00     9575.    6526.    2385.   161.69

      HYDROGRAPH AT
+               SUBE3    2320.   9.50     1879.     689.     230.    18.59
```

```
        HYDROGRAPH AT
+                  SUBE4    826.   9.00      626.     212.      71.    5.20

        3 COMBINED AT
+                  COMB5  10679.  15.50    10266.    7346.    2685.  185.48

        ROUTED TO
+                 ROUTE6  10296.  17.50     9984.    7242.    2685.  185.48

        HYDROGRAPH AT
+                   SUBF   1393.  11.50     1238.     537.     181.   15.36

        2 COMBINED AT
+                  COMB6  10811.  17.00    10508.    7728.    2866.  200.84

        ROUTED TO
+                 ROUTE7  10723.  18.50    10432.    7693.    2866.  200.84

        HYDROGRAPH AT
+                   SUBG   1797.  10.00     1511.     586.     196.   16.62

        2 COMBINED AT
+                  COMB7  11046.  18.00    10772.    8143.    3061.  217.46


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

REFERENCES

1994 Plat Maps of Story County, Iowa. Harlan, IA: R.C. Booth Enterprises, 1994.

1995 Plat Maps of Boone County, Iowa. Harlan, IA: R.C. Booth Enterprises, 1995.

Barrett, Brad, Transportation Engineer II, Office of Bridge Design, Iowa Department of Transportation. "Interview to Discuss Documentation for IA Department of Transportation PCVAL computer program", December 23, 1996.

Chenoweth, John W. "Effect of Land Treatment Upon Flood Flow." Paper presented at the 1986 Summer Meeting of the American Society of Agricultural Engineers, San Luis Obispo, CA, June 1986.

Chow, Ven Te. Open Channel Hydraulics. 1988 reissue. New York, NY: McGraw-Hill Publishing Co., 1959.

Chow, Ven Te, David R. Maidment and Larry W. Mays. Applied Hydrology. St. Louis: McGraw-Hill, Inc., 1988.

City of Ames. "River Readings data for digital and wire weight stage readings at USGS streamgaging stations." Unpublished data from June 8 - July 31, 1993. Ames, IA, August 1993.

City of Ames. "Analog Statistics Report for the Cameron School Road Stream Gage." Unpublished data from June 23-24, 1994. Ames, IA, June 1994.

City of Ames. "River Readings data for digital stage readings at USGS streamgaging stations". Unpublished data from June 13-24, 1994. Ames, IA, July 1994.

City of Ames. "Water Plant Survey Book No. 1." Unpublished survey data entered July 20, 1993 through August 6, 1994. Ames, IA.

Correia, F.N. and H. Morel-Seytoux. "OMEGA: A physically-based rainfall-runoff model for simulation and real-time forecast of river flows." In Systems Analysis Applied to Water and Related Land Resources, Proceedings of the IFAC Conference held in Lisbon, Portugal 2-4 October 1985, edited by L. Valadares Tavares and J. Evaristo DaSilva, 1-5. New York: Pergamon Press, 1986.

Coy, D. "Instructions for Using IDOT PCVAL.BAS Program." Unpublished procedure written February 1991. Iowa Department of Transportation. Ames, IA, February 1991.

DeGroot, William G. "Flash Flood Warning in the Denver Metropolitan Area." In Proceedings of the Second Conference on Flash Floods of the American Meteorological Society, Atlanta, GA, March 18-20, 1980, 201-204. Boston: American Meteorological Society, 1980.

EarthSat. "Floodwatch." [http://www.earthsat.com/flood/whatis.html], 25-May-1996a.

EarthSat. "Watershed Modeling Systems." [http://www.earthsat.com/flood/wms.html], 25-May-1996b.

Feldman, Arlen D. Notes from "Technology and Innovation in Water Resources Management." Presentation at the 24th Annual ASCE Environmental and Water Resources Design Conference held 7 March 1996, Ames, IA, March, 1996.

Fischer, Edward E. and Norwood B. Melcher and Scott P. Kluesner. Statistical Summaries of Selected Iowa Streamflow Data through September 30, 1988. Iowa City, IA: U.S. Geological Survey, 1990, 254-257.

Fleming, G. "Case Studies on Real-time River Flow Forecasting." In River Flow Modeling and Forecasting, edited by D.A. Kraijenhoff and J.R. Moll, 329-365. Boston: D. Reidel Publishing Company, 1986.

Glanville, Thomas D. "Flood prediction and warning program for Squaw Creek at Ames, Iowa." Ph.D. dissertation, Iowa State University, 1987.

Gupta, Ram S. Hydrology and Hydraulic Systems. Englewood Cliffs, NJ: Prentice Hall, 1989.

Hamilton County Farm & Home Plat & Directory. Belmond, IA: Farm & Home Publishers, Ltd., 199?.

Hardin County Farm & Home Plat & Directory. Belmond, IA: Farm & Home Publishers, Ltd., 1994.

Iowa Department of Transportation. PCVAL Computer Program for Determining Stage-Discharge Curves. Last revision: August 11, 1987.

King, John F., Donald W. Newton and Hubert S. Pearson. "Gatlinburg, Tennessee, Flood Warning and Evacuation System." In Proceedings of the Second Conference on Flash Floods of the American Meteorological Society, Atlanta, GA, March 18-20, 1980, 205-212. Boston: American Meteorological Society, 1980.

Lee, B.Y. "A Real-time Rainfall Data Acquisition System." In Microprocessors in Operational Hydrology, Proceedings of the technical conference on the use of microprocessors in operational hydrology held in Geneva, Switzerland 4-5 September 1984, edited by the World Meteorological Organization, 59-68. Boston: D. Reidel Publishing Company, 1986.

Linsley, Ray K. and Joseph B. Franzini. Water Resources Engineering. St. Louis: McGraw-Hill Book Company, 1979.

Luker, Steve, Scott A. Samson, and William W. Schroeder. "Development of a GIS Based Hydrologic Model for Predicting Direct Runoff Volumes." In Proceedings of the Symposium on Geographic Information Systems and Water Resources, edited by John M. Harlin and Kenneth S. Lanfear, 303-311. Bethesda, MD: American Water Resources Association, 1993.

Munson, Bruce R., Donald F. Young and Theodore H. Okiishi. Fundamentals of Fluid Mechanics. New York, NY: John Wiley & Sons, 1990.

O'Brien, Kevin J. "Real-time Data Verification." In Computer Applications in Water Resources. Proceedings of the Specialty Conference sponsored by the Water Resources Planning and Management Division of ASCE held in Buffalo, NY 10-12 June 1985, edited by Harry C. Torno, 764-769. New York: ASCE, 1985.

Owen, James, H. "Concerns of Local Officials about Flood Warning Programs.: In proceedings of the Second Conference on Flash Floods of the American Meteorological Society, Atlanta, GA, March 18-20, 1980, 231-237. Boston: American Meteorological Society, 1980.

Page, Melvin E. [pagem@etsuarts.east-tenn-st.edu]. "A Brief Citation Guide for Internet Sources in History and the Humanities." [http://www.iastate.edu/~wsthune/cp/ecites.txt], 11-May-1996.

Parrett, Charles, Nick B. Melcher and Robert W. James, Jr. Flood Discharges in the Upper Mississippi River Basin, 1993. U.S. Geological Survey Circular 1120-A. Denver, CO: U.S. Government Printing Office, September 1993.

Partial Plans of 150' x 20' High Truss Bridge General and Situation Plans. Story County Project FA 895(1). [E18 over the Skunk River bridge] July 17, 1946.

Partial Plans of Boone County Project S-1284(7) Sheet No. 2. Plan for E-18 over Squaw Creek bridge with site plans. February 1963.

Partial Plans of the Proposed South Squaw Valley Bridge. Story County Road Plan and Profile Project #F-182. February 22, 1980.

Proceedings of the Second Conference on Flash Floods of the American Meteorological Society, Atlanta, GA, March 18-20, 1980. Boston: American Meteorological Society, 1980.

Proceedings of the Symposium on Geographic Information Systems and Water Resources, edited by John M. Harlin and Kenneth S. Lanfear. Bethesda, MD: American Water Resources Association, 1993.

Rohde, F.G. and M. Haase and CH Gitschel. "Computer Aided Generation and Operation of Hydrologic Simulation Models." In Computational Methods in Water Resources X, Volume 2, edited by A. Peters, G. Wittum, B. Herrling, V. Meissner, CA. Brebbia, W.G. Gray, and G.F. Pinder, 1473-1480. Boston: Kluwer Academic Publishers, 1994.

Rooke. "National Hydrologic Warning Council Annual Report." [http://www.io.com/~rooke/alert/nhwc.html], 3-May-1996a.

Rooke. "ALERT Flood Warning." [http://www.io.com/~rooke/alert/alert.html], 25-May-1996b.

Rooke. "SAAS ALERT Users Group." [http://www.io.com/~rooke/alert/saas.html], 25-May-1996c.

Sentar. "Flood Management Project Overview." [http://iquest.com/~sentar/NASA/Project_Over.html], 3-May-1996.

Sittner, Walter T. "Catchment Response Models in the Computer Age." In Computer Applications in Water Resources. Proceedings of the Specialty Conference sponsored by the Water Resources Planning and Management Division of ASCE held in Buffalo, NY 10-12 June 1985, edited by Harry C. Torno, 749-755. New York: ASCE, 1985.

Snyder & Associates, Inc. Final Report: Skunk River/Squaw Creek Flood Plain Management Study. Ankeny, IA: Snyder & Associates, Inc. April 12, 1996.

U.S. Army Corps of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. COED: Corps of Engineers Editor: Users Manual. Davis, CA: The Hydrologic Engineering Center, 1987a.

U.S. Army Corps of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. HEC-1: Flood Hydrograph Package: Users Manual. Davis, CA: The Hydrologic Engineering Center, March 1987b.

U.S. Army Corps of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. Installation Instructions for Microcomputer Version of HEC-1. Davis, CA: The Hydrologic Engineering Center, June 1, 1988.

U.S. Army Corps of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. modClark: Modified Clark Runoff Simulation: Draft Users Manual. Davis, CA: Hydrologic Engineering Center, June 1995a.

U.S. Army Corps of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. GridParm - DEM2HRAP: A Procedure for Evaluating Runoff Parameters for HRAP Cells from USGS Digital Elevation Models: Draft Users Manual. Davis, CA: Hydrologic Engineering Center, June 9, 1995b.

U.S. Army Corp of Engineers. Water Resources Support Center. The Hydrologic Engineering Center. Advances in Hydrologic Engineering. Volume 3. Davis, CA: Hydrologic Engineering Center, March 1996.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 25 no.6 (1975): 2, 12, 14, 15, 16. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 25 no.7 (1975): 2, 8, 10, 11. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 30 no.6 (1980): 2, 9, 10, 12, 13. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. "15-minute Precipitation Data for June 1984 for Ames 8WSW, Ogden, Story City and Webster City." On 3.5" computer diskette. Asheville, NC: National Climatic Center, 1985.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 34 no.6 (1984): 4, 10, 12, 13. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. "15-minute Precipitation Data for June 1990 for Ames 8WSW, Ogden, Story City and Webster City." On 3.5" computer diskette. Asheville, NC: National Climatic Center, 1991.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 40 no.6 (1990): 4, 11, 14, 15. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 40 no.7 (1990): 4, 11, 14, 15. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. "15-minute Precipitation Data for July 1993 for Ames 8WSW, Ogden, Story City and Webster City." On 3.5" computer diskette. Asheville, NC: National Climatic Center, 1994.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 43 no.6 (1993): 4, 12, 15, 16, 17. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 43 no.7 (1993): 4, 13, 16, 18. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data and Information Service. National Climatic Center. Hourly Precipitation Data- Iowa 44 no.6 (1994): 4, 10, 11, 13, 14. Asheville, NC: National Climatic Center.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration. The NOAA-NASA pathfinder program. University Corporation for Atmospheric Research, August 1994.

"U.S. Department of Commerce: National Oceanic and Atmospheric Administration: Warnings and Forecasts". [http://www.noaa.gov/warnings_and_forecasts.html] 11-May- 1996.

U.S. Department of the Interior. Geological Survey. Water Resources Data-Iowa, Water Year 1980, 80. U.S. Geological Survey Water-Data Report IA-75-1. Iowa City, IA: U.S. Department of the Interior, 1976.

U.S. Department of the Interior. Geological Survey. Water Resources Data-Iowa, Water Year 1980, 123. U.S. Geological Survey Water-Data Report IA-80-1. Iowa City, IA: U.S. Department of the Interior, 1981.

U.S. Department of the Interior. Geological Survey. Water Resources Data-Iowa, Water Year 1984, 84. U.S. Geological Survey Water-Data Report IA-84-1. Iowa City, IA: U.S. Department of the Interior, 1985.

U.S. Department of the Interior. Geological Survey. Water Resources Data-Iowa, Water Year 1990, 121. U.S. Geological Survey Water-Data Report IA-90-1. Iowa City, IA: U.S. Department of the Interior, 1991.

U.S. Department of the Interior. Geological Survey. Water Resources Data - Iowa, Water Year 1993, 123. U.S. Geological Survey Water-Data Report IA-93-1. Iowa City, IA: U.S. Department of the Interior, 1994.

U.S. Department of the Interior. Geological Survey. Water Resources Division. Bulletin No. 7: Iowa Highway Research Board: Drainage Areas of Iowa Streams. Iowa: Iowa State Highway Commission and Iowa Natural Resources Council, March 1974.

U.S. Department of the Interior. Geological Survey. Water Resources Division. "Instantaneous Gage Height Graph for Squaw Creek Gage in Ames, IA July 1993." Iowa City, IA: U.S. Geological Survey, printed June 1994.

U.S. Department of the Interior. Geological Survey. Water Resources Division. "Expanded Rating Table for Squaw Creek at Ames, IA Gage # 05470500." Processed 9-1-94. Iowa City, IA: U.S. Geological Survey, 1994.

U.S. Geological Survey and the National Weather Service. "Stream Gaging and Flood Forecasting". [http://h2o.er.usgs.gov/public/wid/FS_209-95/mason-weigner.html], May 11, 1996.

Wahl, Kenneth L., and Kevin C. Vining and Gregg J. Wiche. Precipitation in the Upper Mississippi River Basin, January 1 through July 31, 1993. U.S. Geological Survey Circular 1120-B. Denver, CO: United States Government Printing Office, 1993.

Wilson, J.D. "Floodplain Management Program Spawns Massive Data Collection Network." Earth Observation Magazine, May 1995, 31-35.