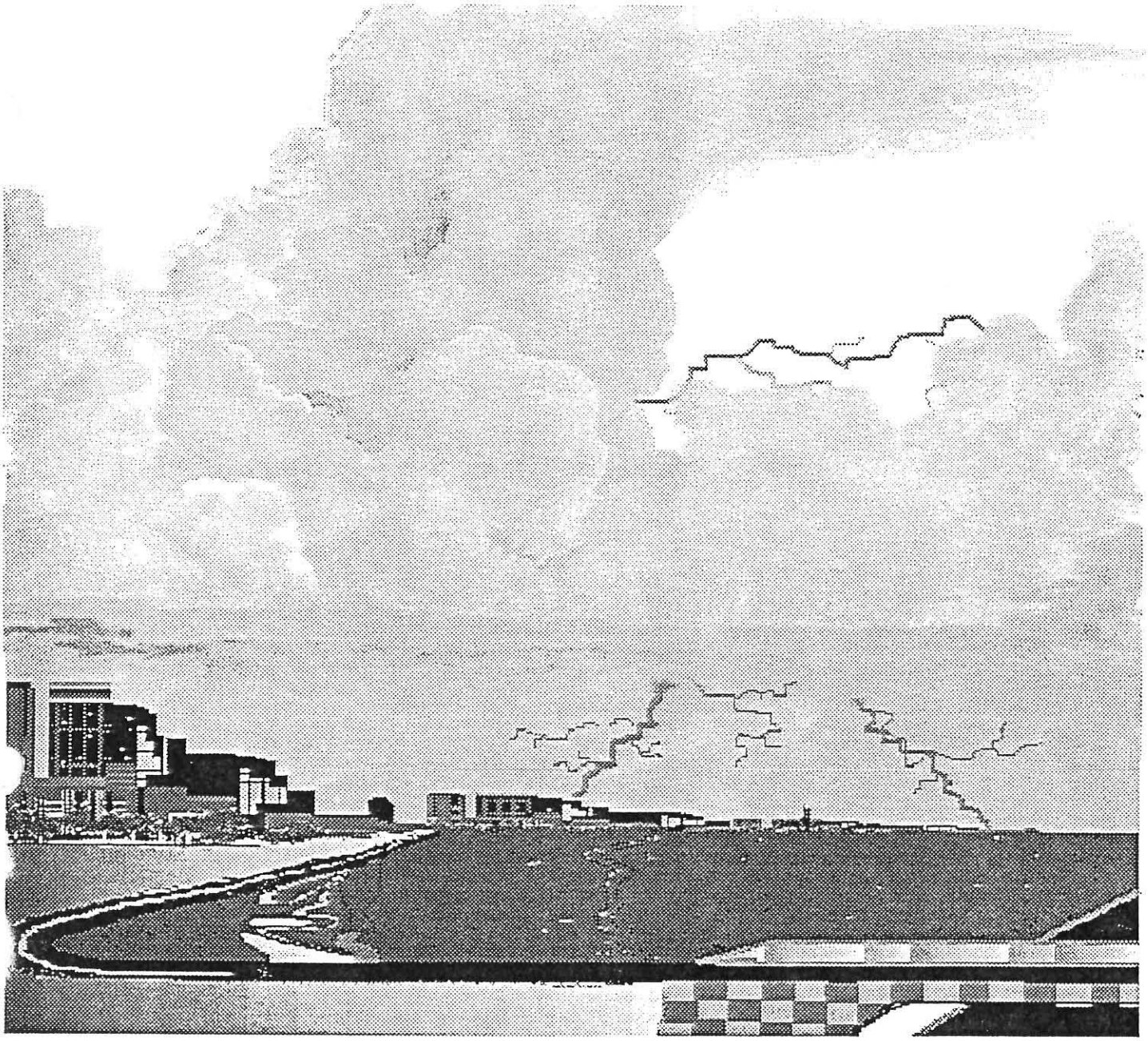


THE 1992 FLASH FLOOD PREDICTION PROGRAM (F2P2) ANNUAL OPERATIONS REPORT HMS REPORT No.93-5

to

Urban Drainage and Flood Control District
Denver, Colorado

by

Henz Meteorological Services
2480 W. 26th Ave. Suite 310B
Denver, Colorado

February 1993

1.0 Introduction

Urban Drainage & Flood Control District (UDFCD or District) has funded a Flash Flood Prediction Program (F2P2) since May 1979. The F2P2 was established as a response to the disastrous Big Thompson Flash Flood of July 31, 1976 in Larimer County. The F2P2 contracts the value-added weather forecasts of a Private Meteorological Service (PMS) to augment the traditional forecast services of the National Weather Service (NWS) for the six county District region. The forecast area supported is shown in Figure 1 and includes over 80 per cent of Colorado's population in roughly a 1600 square mile area. Terrain in the region varies from the rolling populated prairies of Arapahoe and Adams Counties to highly urbanized Denver County to the rugged plains-foothills-mountain interfaces of Jefferson, Boulder and Douglas Counties.

Henz Meteorological Services (HMS) of Denver was the Private Meteorological Service for the 1992 F2P2. HMS provided similar services for the 1990 and 1991 F2P2's. HMS forecast services were prepared by John Henz, Bryan Rappolt and, briefly, Frank Robitaille during the 1992 season. The season began on 15 April 1992 and was extended through 22 September 1992 or 161 days. The season was extended beyond 15 September due to a persistent monsoon flow over the state. Normal operational hours were from 0700L to 2200L and covered 2,415 hours. Overnight operations added an additional 115 hours of support time for a total of 2,530 hours of F2P2 activity.

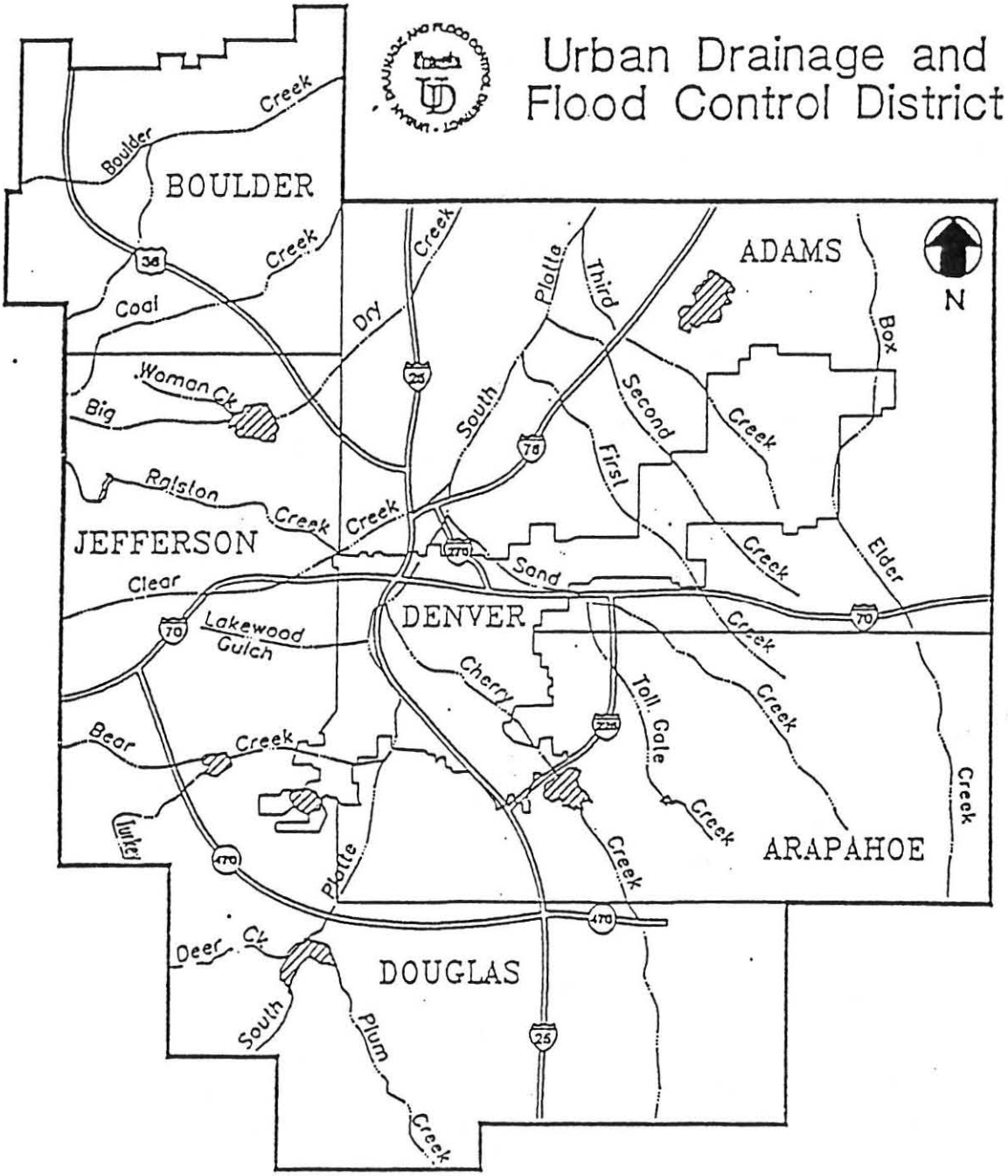
The F2P2 required a continuous Metwatch of the District for the entire period using radar, satellite, conventional surface and upper air observations and local ALERT and mesonet networks. These observations were used to prepare predictions and specialized F2P2 products. These products included daily Heavy Precipitation Outlooks (HPO), MESSAGE 1, 2, 3 and 4's, update statements, Quantitative Precipitation Forecasts (QPF), Storm-Traks and special requests from District members. The remainder of the report will outline the operations of the 1992 F2P2, the results of its predictions, identification of significant storm events and recommendations for the 1993 season.

2.0 F2P2 Operations Products

The F2P2 is designed to offer a supplementary weather information source concerning heavy precipitation, urban flooding and flash flooding threat to the six participating District Counties and the cities within those counties. Additionally direct basin specific support is rendered to the seven District basin warning plans which exist. Four specific F2P2 products exist in addition to voice support. These products are Heavy Precipitation Outlooks (HPO), Internal Message Status's (IMS), Quantitative Precipitation Forecasts (QPF) and HMS StormTrack Predictions (FAX Map). A brief description and example of each product is presented on the next page as it was recently described by UDFCD. Please note that the use of EBB refers to the District's Electronic Bulletin Board and FAX refers to the transmission of a product by either the HMS internal fax card or fax machine as used in the program.

FIGURE 1

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
FLASH FLOOD PREDICTION PROGRAM (F2P2)
BACKGROUND INFORMATION HANDOUT



VICINITY MAP

HMS Heavy Precipitation Outlook (HPO)

HPO's are available every day by 11:00AM and updated by 4:00PM when appropriate. This forecast information can be obtained by either EBB or FAX communications. The daily outlook will typically include a descriptive header and a single paragraph summarizing the weather forecast. This paragraph will be followed by a table providing a county-specific prediction of flash flood potential, expected rainfall and other associated weather.

HMS Internal Message Status (IMS)

IMS's will be communicated via FAX and EBB when internal alerts, flash flood watches or flash flood warnings are issued to local governments within the District (i.e. MESSAGE 1, MESSAGE 2, MESSAGE 3 and MESSAGE UPDATES). All users of this information should be familiar with current F2P2 procedures including the issuance of "RED FLAG" messages. The purpose of the IMS report is to keep local officials updated regarding the active message status for the entire District. The IMS will typically include a descriptive header and paragraph summarizing the weather situation. This will be followed by a table indicating the specific messages issued for each F2P2 contact point. The table will also list each area's valid and prime times for storm activity along with anticipated problems.

HMS Quantitative Precipitation Forecast (QPF)

QPF's will be communicated via FAX and EBB when the potential exists for point rainfall accumulations to exceed 1.5 inches in one hour or less. The QPF product is designed primarily for technical personnel familiar with the hydrologic procedures and the regional major drainage system of the District. EBB users require a separate login to obtain this detailed forecast. It should be noted that both the HPO and IMS bulletins generally contain quantitative predictions of rain but, in limited detail. The purpose of the QPF product is to provide more information in terms of predicted rainfall intensities and storm duration, storm total estimates, probabilities of occurrence for specific drainage basins, storm classification, etc.

HMS StormTrack Prediction (FAX Map)

Storm track predictions will only be available to FAX users on MESSAGE days. The FAX Map will show the predicted storm tracks and associated zones of storm influence. The predicted storm movement timing will also be indicated on the map. When appropriate, this product will be updated 30-60 minutes prior to flooding occurrence to show refined predictions and specific basins affected.

The EBB and FAX products are not intended to replace voice communications between HMS and dispatchers. The major advantages of hard copy products are: 1) daily weather forecasts are available; 2) written information can be quickly obtained and re-disseminated if desired; 3) the FAX Map can be easily interpreted ; 4) early communications with HMS and NWS can be initiated by local authorities before situations develop; and 5) lead times for implementing emergency action plans will be increased.

Each of these four products are delivered to local government entities participating in the District's F2P2. In turn many of them further transmit these products to internal focal points for action. During the 1992 season HMS delivered 7,084 routine HPO faxes to these groups. It is estimated that on a daily basis the 22 primary HPO reception points fax these HPO's to an additional 200 plus locations. Clearly the program has a more far reaching extent than the numbers alone would indicate.

Additionally HMS originated over 6,070 IMS, QPF and StormTrack products via FAX to participating agencies. Each of these products were followed up by a telephone verification of reception and discussion of the product. HMS logged over 3,000 storm-related telephone interactions during the program, emphasizing the strong technical "touch" of the program in the local community. In anticipation of these numerous communications HMS installed three dedicated telephone lines: two for voice and one for fax and data communication in its redesigned weather center. Even these three lines were inadequate to handle the volume of communications generated during peak storm periods. HMS frequently used its remaining three published business lines to handle the overload periods. New technology appears to have offered a solution - US West's Broadcast Fax - which will be tested during the 1993 season.

An example of these products as issued for the urban flooding event of July 20, 1992 is offered in Figures 2 - 8. The morning 1100AM MDT HPO is shown in Figure 2. It headlines the threat of urban flooding during the evening rush hour in the southern half of the District. The QPF issued at 300PM MDT for the afternoon storms is shown in Figure 3 with the highest storm probabilities given for south side basins. At the same time the QPF was issued, MESSAGE 1's were issued by phone and FAX and followed up by the IMS shown in Figure 4. As of 330PM, MDT all MESSAGES had been issued to counties and cities which were forecast to be affected. At 400PM, MDT the STORMTRAK shown in Figure 5 was faxed and identified the specific area to be affected by the storms from 400PM to 600PM, MDT.

Figures 6 and 7 show the verified QPF versus ALERT network measured rainfall for the storm. Figure 8 is a picture from the July 21, 1992 issue of the Rocky Mountain News which shows some of the street flooding encountered during the evening rush hour. The storm period was effectively identified and each product provided a value-added service in identifying the areas to be affected and the correct time periods during which the activity would occur..

The next section of this report will deal with the operational results of the 1992 program as compared with prior seasons. Verification will be presented for MESSAGES issued to each county and city for all MESSAGE days.

FIGURE 2

HENZ METEOROLOGICAL SERVICES HEAVY PRECIPITATION OUTLOOK
DATE/TIME: MONDAY,1110AM JULY 20, 1992

.... HEAVY RAINS FROM SEVERE T-STORMS COULD PRODUCE URBAN STREET AND SMALL STREAM FLOODING FOR THE EVENING RUSH HOME.....

HMS is very concerned that today will be the first of a three day weather barrage by Mother Nature that will test the emergency response capabilities of the District. For today slow-moving t-storms could produce a combination of large hail and locally heavy rainfall. Hail size could reach 3/4 -1 1/2" diameter or larege enough to clog drains and cause damage. Rainfall could range from 0.25"-0.50"/15min to 0.75"-1.25"/30min with storm totals of 1.00"-2.75". Prime time will run from 200PM to 700PM. Today's weather focus will be on the plains in areas where afternoon temperatures peak in the mid-70's. The early fingers point at eastern Jefferson, ssssouther Denver, northern Douglas and western Arapahoe Counties for MESSAGE 1'S. WE WILL UPDATE AT 130PM AND URGE YOU TO KEEP UP ON NWS SEVERE WEATHER STATEMENTS.

COUNTY	PRIME TIME	RAINFALL(%)	AND OTHER WEATHER
FOOTHILLS	1200PM -600PM	0.25"-0.50"/15-30MIN (60%)	1/2" HAIL
PLAINS	200PM -700PM	0.50"-1.25"/30MIN(60%)	2.50"/HR(30%)

FIGURE 3

HENZ METEOROLOGICAL SERVICES
QUANTITATIVE PRECIPITATION FORECAST (QPF)
DATE/TIME: 300PM MONDAY, JULY 20, 1992

.....LOCALLY HEAVY RAINFALL POSSIBLE IN STONG TO POSSIBLY SEVERE THUNDERSTORMS.....

An increase in low and mid-level moisture has put the distict in a heavy rainfall threat. Rainfall could approach 1.25"-2.50"/30-60min from strong to severe storms that will develop between 200-400pm in the district. This rainfall will cause street, low lying areas, and small stream flooding. RAPPOLT

HMS QPF PREDICTION

STORM TYPES	FORECAST AMTS	10min	30min	60min	Total	NOTES
EXTREME:		1.30"	1.86"	2.65"	2.75"	
HEAVY:		0.91"	1.30"	1.85"	1.95"	
NUISANCE		0.54"	0.78"	1.11"	1.17"	

BASIN SPECIFIC STORM TYPE / PROBABILITIES (%)

MAJOR BASINS	AMTS: 0.80"	1.85"	2.75"	PROBLEM AREAS
Boulder Creek	30	15	10	EASTERN PLAINS
Big Dry Creek	40	20	10	PLAINS AREAS
Clear Creek	50	25	10	Ralston Creek, Lower Brch.
Bear Creek	60	30	10	Evergreen, Morrison
Central Denver-West	50	20	10	Sloan's Lake, Mousetrap
Central Denver-East	60	30	10	Westerly Creek, I-25
South Side-West	60	30	10	Dutch Creek/SW PLAZA
South Side-East	60	40	20	Littleton, Greenwood V.
Cherry Creek	60	40	20	Goldsmith, I-225
Sand Creek	60	40	20	Toll Gates
First Creek-West	40	20	10	Westminster, Northglenn
First Creek-East	50	25	15	MontBello, New Airport

SUPPLEMENTAL: STORMTRAKS WILL BE ISSUED WITH A 30-60 MIN LEAD.

FIGURE 4

HENZ METEOROLOGICAL SERVICES
INTERNAL MESSAGE STATUS (IMS)
DATE/TIME: 330PM MONDAY 20 JULY 1992....METEOROLOGISTS:
HENZ/RAPPOLT

...MESSAGE 1'S ISSUED FOR NE JEFFERSON, WESTERN ADAMS, WESTERN ARAPAHOE AND DENVER COUNTIES VALID FROM 400PM TO 900PM
NWS TORNADO WATCH VALID FOR ENTIRE DISTRICT UNTIL 900PM....

Isolated severe t-storms are forming to the west of the Distict at this time in a line from southern Larimer to northern Jefferson to northern Park Counties. These storms will cross the District from west to east at 20mph between 400PM and 630PM. The threat of severe weather(tornado and/or large hail) and locally heavy rianfall will accompany the storms.

At this time we feel the most active storm trak will run form northern Jefferson County across Denver County into western Aarapahoe County from 430PM until 630PM. STORM RAINFALL COULD REACH 0.75" -1.50"/30-45MIN AND PRODUCE STREET FLOODING AND SMALL STREAM FLOODING DURING THE RUSH HOUR. SEVERE WEATHER COULD BE A FACTOR SO STAY TUNED TO NWS SEVERE WEATHER STATMENTS. HENZ

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M-1 ISSUED FOR DENVER, ADAMS, ARAPAHOE AND JEFFERSON COUNTIES

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COUNTY	T-STORM RISK	RAINFALL RATES	OTHER WEATHER
JEFFCO	330PM -900PM(70%)	0.50"/15MIN TO 1.50'/30-45MIN	
DENCO/ARAPCO/ADCO	"" "	" " "	"
DOUGCO	430PM - 900PM(80%)	0.50" -1.75"/60MIN	
BOULDER	400PM -900PM(60%)	0.25" -0.50"/30MIN	

==========

SYNOPSIS: SUPPLEMENTAL: QPF ISSUED..STORMTRAK ISSUED

WARNING: Verbal communications take precedence over this internal message status report. Note the time this message was issued and confirm current message status by calling your Police or Sheriff Dispatcher or contact HMS at 458-1464.

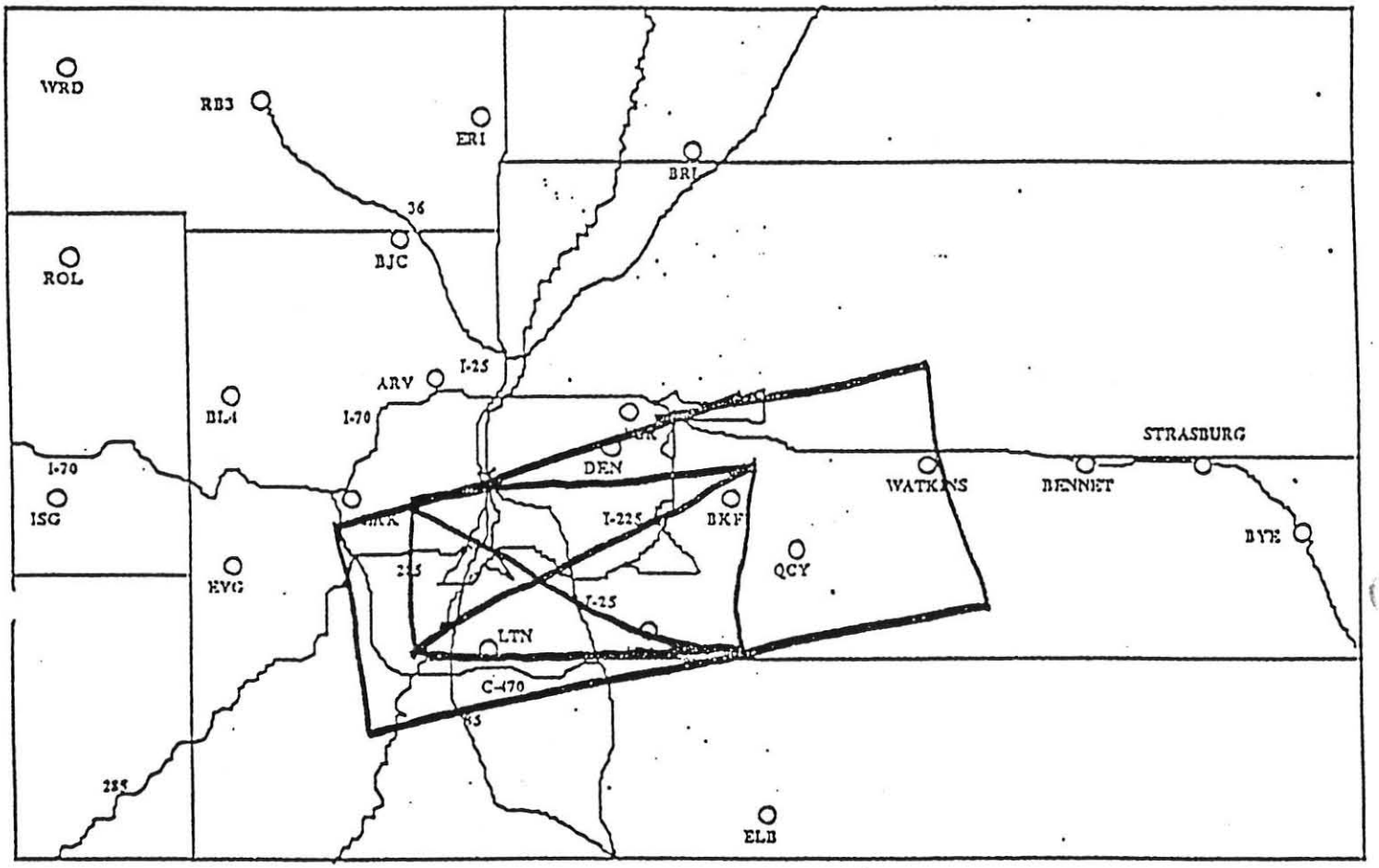
FIGURE 5

HMS STORMTRAK

UDFCD FLASH FLOOD PREDICTION PROGRAM (F2P2)

HENZ METEOROLOGICAL SERVICES.....STORMTRAK PREDICTION

DATE: 7-20-92 TIME: 4PM VALID: 4PM-630PM



1 LINE OF SVR T-STORMS WILL EXPLODE 4PM - 5PM FROM W. LAKEWOOD - S. DENVER - AURORA

2. 1-2" /hr RAINFALL + THREAT OF TORNADO + LARGE HAIL IN BOX AREA

LITTLETON, DENVER + AURORA HAVE SEVERE WEATHER THREAT.

3.

FIGURE 6

JULY 20, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5MC#430	5MC#510	5MC#520	5MC#540	5MC#420
0	0	0	0	0	0	0	0	0
5	0.06	0.10	0.14	0.04	0.04	0.04	0.08	0.12
10	0.12	0.20	0.28	0.04	0.59	0.08	0.16	0.20
15	0.39	0.66	0.98	0.16	0.83	0.36	0.47	0.32
20	0.66	1.11	1.58	0.32	0.95	0.56	0.67	0.36
25	0.72	1.21	1.72	0.36	0.99	0.68	0.75	0.40
30	0.78	1.30	1.86	0.44	1.03	0.80	0.75	0.40
35	0.88	1.40	2.01	0.52	1.07	0.88	0.75	0.40
40	0.98	1.50	2.16	0.52	1.11	0.92	0.83	0.44
45	1.03	1.60	2.31	0.56	1.11	0.92	0.91	0.52
50	1.07	1.70	2.46	0.64	1.11	1.00	0.91	0.52
55	1.09	1.80	2.56	0.64		1.04	0.95	0.52
60	1.11	1.85	2.65	0.64		1.04	0.95	
65	1.13	1.90	2.70			1.04	0.95	
70	1.15	1.93	2.73					
75	1.17	1.95	2.75					
80	1.17	1.95	2.75					
85	1.17	1.95	2.75					
90								

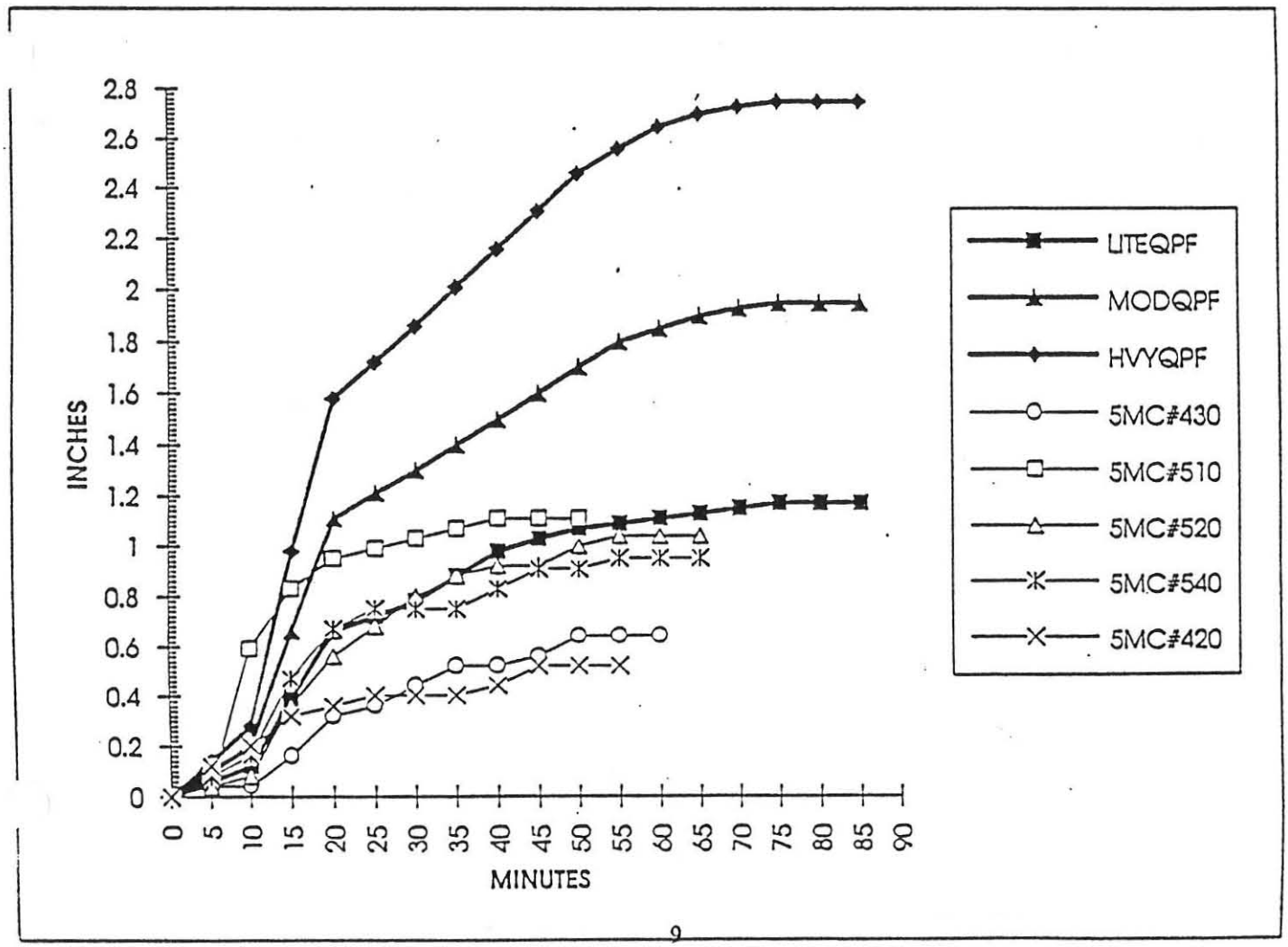


FIGURE 7

JULY 20, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5M#600	5MC#600	5M#610	5MC#610	5M#620	5MC#620
0	0	0	0	0	0	0	0	0	0
5	0.06	0.10	0.14	0.12	0.12	0.20	0.20	0.24	0.24
10	0.12	0.20	0.28	0.24	0.36	0.35	0.55	0.24	0.48
15	0.39	0.66	0.98	0.35	0.71	0.31	0.86	0.00	0.48
20	0.66	1.11	1.58	0.04	0.75	0.43	1.29	0.00	0.48
25	0.72	1.21	1.72	0.04	0.79	0.08	1.37	0.00	0.48
30	0.78	1.30	1.86	0.00	0.79	0.08	1.45		
35	0.88	1.40	2.01	0.04	0.83	0.04	1.49		
40	0.98	1.50	2.16	0.04	0.87	0.00	1.49		
45	1.03	1.60	2.31	0.00	0.87	0.00	1.49		
50	1.07	1.70	2.46	0.00	0.87	0.00	1.49		
55	1.09	1.80	2.56	0.00	0.87				
60	1.11	1.85	2.65						
65	1.13	1.90	2.70						
70	1.15	1.93	2.73						
75	1.17	1.95	2.75						
80	1.17	1.95	2.75						
85	1.17	1.95	2.75						
90									

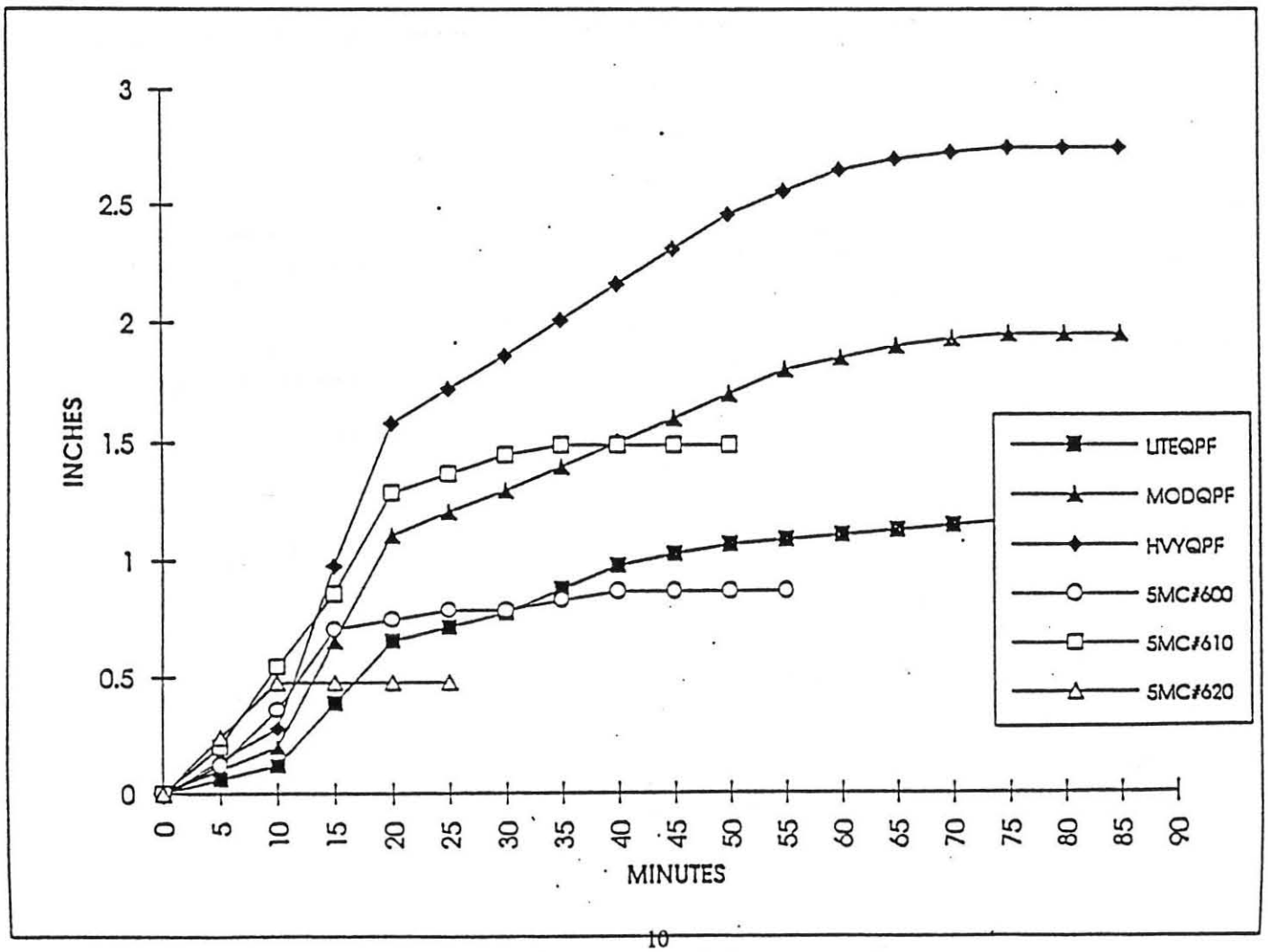
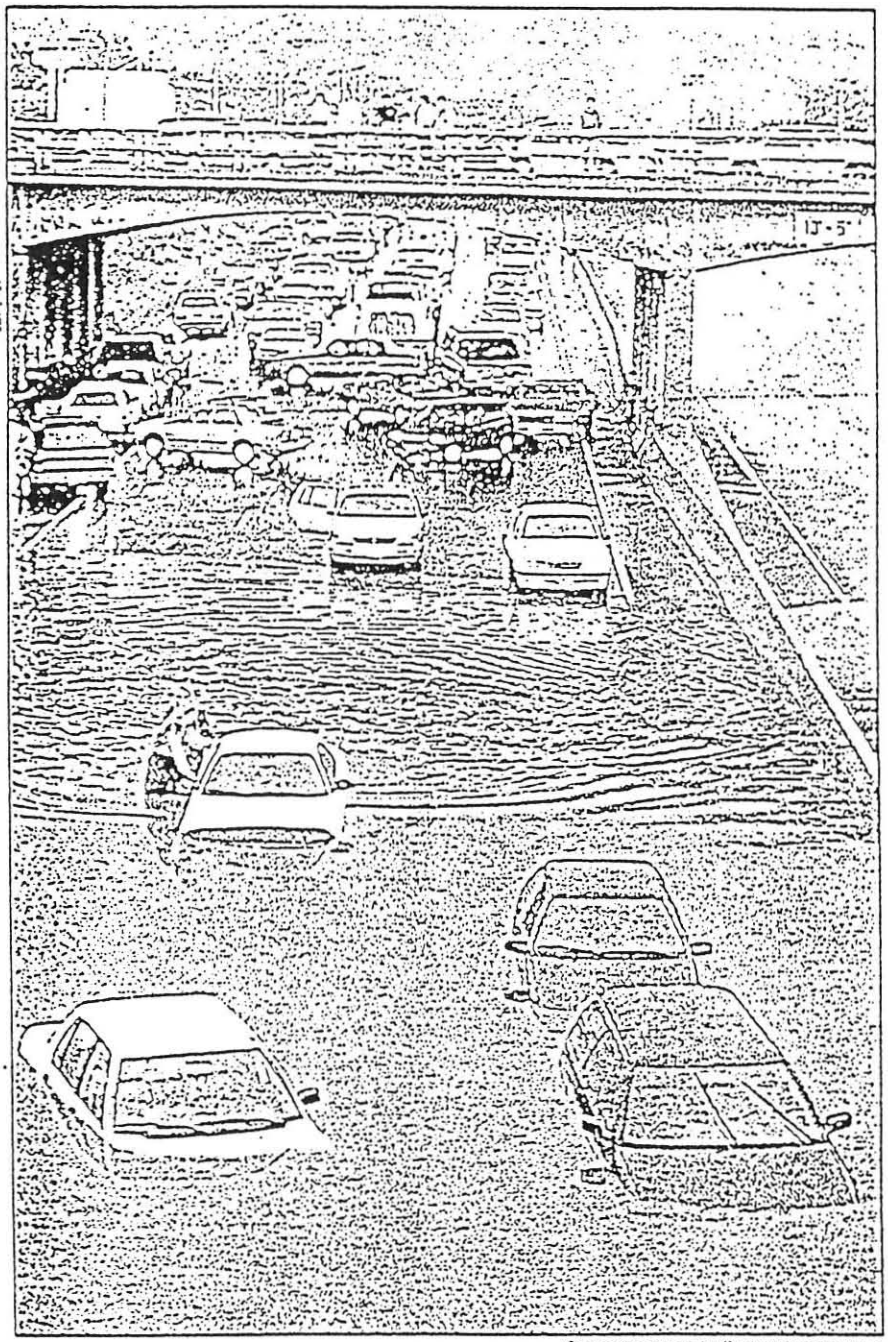


FIGURE 8

Rocky Mountain News

July 21, 1992 DENVER, COLORADO 134th year, No. 90

Rain snarls rush-hour traffic



George Kochaniec Jr./Rocky Mountain News

A brief, intense cloudburst during the afternoon rush hour floods underpasses such as this one at East Evans Avenue and Interstate 25 in south Denver. Traffic was stopped in both directions. Numerous lightning strikes also were reported Monday in the metro area, in some cases causing power outages.

:S

:n slinging guns

:e of the nation's 70 vners are women. Front structors say most of are female. *Page 28*

vestment could pay

A $26 million effort by the U.S. Olympic Committee to aid athletes could pay off in medals when the Summer Games start Saturday. *Page 39*

IY

ng image battle

American's hunters have an image problem, says outdoor writer Ed Dentry. They contribute millions to wildlife programs but have not communicated their message well to the U.S. public. *Page 48*

RKETS

-28.64	NASDAQ	-6.24
-2.03	S&P 500	-3.01
+1.20	Oil	+0.21

INSIDE

s best-selling newspaper
0 daily 434,177 Sunday
information, call 892-6397
nformation, call 892-7111
her information, call 892-5000

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3.0 1992 F2P2 Operations Results

MESSAGE Verification

The primary service rendered by the F2P2 to participating local governments is the issuance of value-added weather forecasts of urban and stream flooding and locally heavy rainfall. HMS indicates the potential for these events in a series of MESSAGES issued directly to the users by phone, FAX and EBB. The criteria for MESSAGE issuance is shown in Figure 9. These criteria were developed with the District to identify rainfall criteria directly related to the production of flooding events. Evaluations of program performance are based on rainfall and event occurrences which verify these criteria. An effort has been made to verify all program forecasts by these criteria and the results are presented in Table 1.

A comparison is presented in Table 1 of all F2P2 seasons since 1979. The table shows the number of days MESSAGES were issued each season (a MESSAGE day), the number of MESSAGE days which recorded a heavy rain event (> 1"/hour) or flooding event and the number which did not record an event in the District. The accuracy indicates the percentage of correct MESSAGE day forecasts while the false alarm rate indicates the number of days incorrectly identified as a MESSAGE day. The probability of detection indicates the percentage of days which experienced a heavy rainfall or flooding event and had appropriate MESSAGES issued.

The 1992 season was slightly below average in the number of and the intensity of thunderstorm day activity compared to 14 year averages. Only 29 MESSAGE days were noted in 1992 compared to the average of 35 MESSAGE days. HMS correctly forecasted the occurrence of all the days which experienced a MESSAGE-level rainfall or flooding event. However, four days were over forecasted, with no reports of flooding or heavy rainfall. On three of the four days, active thunderstorms crossed the District but produced no flooding problems.

Customer support levels can best be judged by reviewing the individual MESSAGE verification statistics. Table 2 shows a comparison of individual MESSAGE statistics for the 1987, 1991 and 1992 F2P2 seasons. The verification of MESSAGES on a county and city basis was begun experimentally in 1987 when the first ALERT Flood Detection Networks were made operationally available to the PMS. Note that less than 50 percent as many MESSAGES were issued in 1992 as in the other two operational seasons. Part of this drop can be attributed to a decrease in the number of heavy thunderstorms while part of it is due to an effort to improve "basin-level" forecasting by HMS meteorologists.

FIGURE 9

UDFCD FLASH FLOOD PREDICTION PROGRAM
MESSAGE CRITERIA

Message 1: Issued primarily to alert local governments to the threat of nuisance street flooding due to thunderstorm rainfall when storm total rainfall is 0.50" -1.00" in one hour or less. When rainfall is 1.00" to less than 3.00" in one hour or more urban and rural street and stream flooding becomes a more significant problem. M-1 leadtimes of 1 hour or more are desireable.

Rainfall intensity criteria: any of the intensities below should prompt a Message 1 issuance

1.00"/ 60 minutes

0.75"/ 30 minutes

0.50"/ 10 minutes

Message 1, RED FLAG: Issued whenever rainfall rates will exceed 1.00"/30 and the storm is considered imminent.

Message 2: Issued to local governments when the threat of potential life threatening urban street and stream flooding is predicted. A M-2 is the equivalent of a Flash Flood Watch.

M-2 Rainfall intensity criteria: 3.00" /hour

Message 3: Issued to local governments whenever a life-threatening flash flood is imminent. M-3's are issued in accordance with basin-specific warning plans if available or at the discretion of the meteorologist.

Quantitative Precipitation Forecasts(QPF) are issued whenever a M-1 is issued and rainfall rates will predicted to equal or exceed 1.50"/hour or 1.00"/30minutes.

Table 1

UDFCD F2P2 **DISTRICT-WIDE** MESSAGE DAY VERIFICATION: 1979 - 1992

Year	Message 1 Days	Verified Hits	Misses	Accuracy	False Alarm	Probability of Detection
GRD Weather Center (District Era)						
1979	26	17	9	65%	35%	85%
1980	35	23	12	66%	34%	100%
1981	40	31	9	77%	23%	100%
1982	42	34	8	81%	19%	100%
	143	105	38	73%	27%	97%
Henz, Kelly & Associates (County Era)						
1983	37	32	5	86%	14%	100%
1984	38	32	6	84%	16%	100%
1985	28	25	3	89%	11%	100%
1986	35	30	5	86%	14%	97%
1987	47	40	7	85%	15%	100%
1988	28	24	4	86%	14%	100%
1989	31	26	5	84%	16%	100%
	244	209	35	86%	14%	99.5%
Henz Meteorological Services (Red Flag Era)						
1990	30	26	4	87%	13%	93%
1991	42	31	11	74%	26%	100%
1992	29	25	4	86%	14%	100%
	101	82	19	81%	19%	98%
Total	488	396	92	81%	19%	98.7%

Message Day = Issuance of a Message 1: Stream of Urban Flooding Forecast anywhere in District usually due to 1"/hour or more

Hit = Verification of Message in issued County

Miss = No verifications

Table 2

Annual Verification Comparison for UDFCD (District)

Year	M-Days	Hits	Misses	Percent Accuracy	Percent False Alarm	Probability of Detection	Total M-1's	Hits	Misses	Percent Accuracy
1987	47	40	7	85	15	100	353	153	200	44%
1991	42	31	11	74	26	100	293	155	138	53%
1992	29	25	4	86	14	100	143	81	62	57%

Table 3

County / City Message-1 Verification

	Total County and City			County Verification			City Verification		
Year	Number of M-1's	Hits	Percent Hit	County M-1's	Hits	Percent Hit	City M-1's	Hits	Percent Hit
1991	293	155	53%	185	98	53%	108	57	53%
1992	143	81	57%	109	66	61%	34	15	44%

Table 4

Red Flagged M-1's (RF)

Year	Total M-1's	RF's	RF Hits	% RF Hits	% RF's
1991	293	171	156	91%	58%
1992	143	85	81	95%	59%

Year	Number of RF's	RF Hits	Percent RF Hits	County RF's	County RF Hits	Percent Hit	City RF's	City RF Hits	Percent Hit
1992	85	81	95%	69	66	96%	16	15	94%

It is important to note the almost 30 percent increase in the accuracy of individual MESSAGES since 1987. The 1987 F2P2 season was very representative of the 1980's F2P2 forecasting skills. HMS suggests that the increase in individual MESSAGE accuracy has been due to new forecast techniques developed from 1990 to 1991 as reflected in the HMS StormTrak product.

A comparison of the MESSAGE verification on the county and city basis can be found in Table 3 which shows almost two-thirds of the county MESSAGES verified while just less than half of the city MESSAGES hit. It should be noted that the use of the terms county and city could be misleading. UDFCD includes less than 25 percent of Boulder County, 50 percent of Jefferson County, 40 percent of Adams County, 35 percent of Arapahoe County and 25 percent of Douglas County on an area basis. It does cover all of the City and County of Denver. Therefore, a county MESSAGE can only be verified as a "hit" only if it verifies in the District portion of that county, not just anywhere in the county.

While less than 60% of the total MESSAGES verified, their utility to the users was improved by the use of a MESSAGE Red Flag issuance. A MESSAGE indicates to the user that the potential exists for a flooding event later during the day. A Red Flagged MESSAGE indicates that the potential of a flooding event will be realized in the next 30-60 minutes. In other words the RED FLAG means action is needed. Table 4 shows the verification for the Red Flagged MESSAGES. While only about 60 percent of the MESSAGES were Red Flagged, 95 percent verified. This high accuracy rate for the Red Flags indicates why the MESSAGE program is such a success with the users. They can rely on it. A summary of the individual MESSAGES and Red Flags by day, county and city are presented in Table 5. Flash Flood Watches(MESSAGE 2's) and Flash Flood Warnings (MESSAGE 3's) issued by the National Weather Service were also included in Table 5 but were not included in the HMS statistical verification.

Please note that the coordination and cooperation between the NWS and HMS within the F2P2 was the best in 10 years and has re-attained the levels of interaction achieved before 1983. One of the best examples of this cooperation was found during the heavy rainfall and flooding events associated with the passage over the District of the remnants of Hurricane Lester on August 24, 1992. All NWS Watches and HMS MESSAGES verified to the users' benefit. While interaction is not perfect it has become mutually beneficial and productive.

Quantitative Precipitation Forecasts (QPF)

An important operational product in the F2P2 has been quantitative precipitation forecasts (QPF) issued to technical program participants. While a general form of QPF is offered for each county daily in the HPO's, the basin-specific QPF's are only issued when rainfall is forecast to equal or exceed 1.50"/hour or 1.00"/30 minutes. During the 1992 F2P2, QPF's were issued on 15 days. Examples of the verification of the QPF's are presented for 11 of the 15 days in Appendix A.

Table 5. Daily Message Verification by County and City for 1992 Denver F2F2

MESSAGE DAYS FOR THE 1992 FLASH FLOOD PREDICTION PROGRAM															
DATE	FORMS ISSUED				MESSAGE VERIFICATION BY DISTRICT, COUNTY, AND CITY										
	M1	M2	M3	QPF	DISTRICT	BOCO	ARAPCO	DENCO	DOUGCO	ADCO	JEFFCO	AURORA	WHTRDGE	LKWD	ARVADA
6/6/92	X				●		●◆		●◆			●◆			
6/7/92	X				●		●◆	●◆		●		●			
6/8/92	X			X	●	●◆	●◆	●◆	●	●◆	●◆	●◆	●	●	●
			X		⌘	⌘				⌘	⌘				
6/11/92	X			X	●		●◆	●	●◆			●◆			
6/12/92	X				●		●	●			●◆	●	●	●	●
6/19/92	X			X	●	●◆	●◆	●	●◆	●◆	●	●◆			
6/20/92	X				●		●◆	●◆	●◆	●	●◆				
6/21/92	X				●	●◆				●◆	●◆				
6/24/92	X				●		●◆	●◆		●◆		●			
6/25/92	X			X	●	●			●	●◆					
		X			⌘		⌘	⌘			⌘				
6/26/92	X				●	●	●◆		●◆	●	●				
7/1/92	X			X	●		●◆		●◆						
7/12/92	X			X	●		●◆	●	●◆		●				
7/15/92	X				●		●◆	●	●◆			●◆			
7/16/92	X			X	●	●									
7/20/92	X			X	●		●◆	●◆		●◆	●◆				
7/21/92	X			X	●		●		●			●			
7/23/92	X				●		●◆	●◆				●◆			
7/24/92	X			X	●	●	●	●	●		●	●			
7/25/92	X			X	●		●	●	●◆	●	●◆	●			
7/26/92	X			X	●	●	●◆	●◆	●◆	●	●	●◆			
8/3/92	X				●		●	●	●	●	●	●			
8/10/92	X			X	●	●			●◆						
8/11/92	X				●		●◆				●◆		●◆	●◆	●◆
8/12/92	X				●						●◆			●◆	
8/17/92	X			X	●	●◆	●	●◆	●◆	●◆	●	●			
8/23/92	X				●	●◆	●◆	●◆	●◆	●◆	●	●			
8/24/92	X	X			● ⌘	●◆	●◆	●◆	●◆	●◆	●◆	●◆	●◆	●◆	●◆
8/25/92	X			X	●		●◆	●◆	●◆	●◆	●	●◆	●	●	●
TOTAL:		2	1	15	29	12	24	19	20	16	18	18	5	6	5

◆ = Red Flag ● = Hit or Correct Forecast ● = Miss or Incorrect Forecast

⌘ = NWS Hit ⌘ = NWS Miss

On two days, no storms occurred within the ALERT FDN's to provide QPF verification, though flooding events were reported, and on two days the MESSAGES did not verify. In general the verification data are very encouraging. In most cases the heavy rainfall occurred in basins where greater than 60 percent probabilities of heavy rainfall were indicated in the QPF bulletin. The time distribution and predicted storm mass curves of rainfall bracketed the ALERT FDN observed rainfall very closely in most cases. The greatest over-forecasts occurred during the August 24, 1992 Hurricane Lester event. On these days no thunderstorms occurred in the District. While general rainfall was accurately predicted in most basins, the heavy QPF associated with a thunderstorm thankfully did not verify in any basin.

HMS began the QPF verification and forecast effort in a detailed manner during the 1988 F2P2. As the number of ALERT FDN's increased from one to seven, the ability to verify QPF's has understandably improved. Prior to 1990 the spotty distribution of FDN's limited QPF verification. HMS is in the process of completing a detailed verification of the QPF's since 1990 and will publish its results at the conclusion of the 1993 season. At this time this verification is deemed too technical for inclusion in this report.

4.0 Significant 1992 Storms

The 1992 thunderstorm season featured an unusual number of high intensity, short duration storms and the rare passage of the decaying remnants of a hurricane's eye over the District. These "front-end dumper" storms closed I-25 twice and flash flooded a significant number of high traffic volume urban streets during rush-hours. The most significant thunderstorm event days will be highlighted below:

June 8: A series of cloud-burst type thunderstorms merged over the northern half of the District closing I-25 north of the Mousetrap in several locations--another storm in the "anniversary day" series.

July 15: A quick-hitting rush hour squall line pounded Arapahoe, Denver and Douglas Counties dropping 1.25"-2.00" in 25 minutes.

July 20: A rapidly forming thunderstorm was enhanced by the Denver cyclone into a brief but intense storm which closed I-25 near Evans at the height of the rush hour snarling travel.

August 10/11: Rare nocturnal thunderstorms erupted over Thornton and moved due south into Douglas County between 10:30PM and 2:00AM. Intense lightning and radar estimated 1-1.5"/30-60 minute rainfall accompanied the core of the storm.

August 24: The decaying eyewall cloud of ex-Hurricane Lester was captured on video radar film loop crossing Douglas and Arapahoe Counties. General rain of 2-3 inches in 12-18 hours produced seasonal peak discharges.

5.0 Concerns and Recommendations

HMS utilizes this portion of the report to identify operational problem areas or matters of concern which became apparent during the operational season and need to be addressed. The primary concern areas during the 1992 season were related to communications, training, and weather radar data availability. The weather radar data availability and display issues were dealt with in a separate HMS report to UDFCD and will not be discussed in this report. The reader is referred to the report entitled, " Review of Radar Options Available to the Urban Drainage & Flood Control District in the 1990's", HMS Report No. 92-11 for additional details.

Communication Concerns

- Overloading of telephone lines slowed transmission of fax products which became an operational problem
- Telephone interaction with county focal points, routine weather data ingest needs and fax needs have become too much for one dedicated, unlisted telephone line
- Use of the UDFCD cellular phone makes remote communications cumbersome at best.

As indicated in the first section of this report, HMS faxed at least 5,412 routine HPO products and an additional 6,070 MESSAGE day fax products. Initially, HMS tried to fax all products on its Canon 850 fax machine. It quickly became apparent that it took over 20 minutes to send each product to the 22 county/city focal points. On days when multiple products were being disseminated, a fax log jam quickly resulted.

The problem was addressed by Bob Hirsekorn of HMS through the addition of new software and an internal fax card in the HMS weather workstation. Bob utilized Microsoft Word for Windows 2.0 to create MESSAGE form templates for the HMS forecasters to use in issuing MESSAGES. He used WinFax Pro2.0 software to transmit the completed templates through an internal fax/modem to the user communication points. By simultaneous use of both the fax card and the fax machine, HMS noted a significant reduction in the fax "log jam" problem. Additionally users reported very favorable comments on the reception of a MESSAGE hard copy for use by dispatchers. It eliminated most misunderstandings of MESSAGE content and eliminated the need to search for a blank MESSAGE form. Although the fax "log jam" problem was significantly reduced, the problem still exists, and further additions to the fax network will only complicate the situation.

The 1992 F2P2 contract required HMS to maintain one dedicated, unlisted telephone line to insure communications with the NWS during MESSAGE days and to facilitate F2P2 communications. HMS installed three unlisted lines for program use during 1992; one line for fax communication, one line for voice communication and one line for weather data ingest (mesonet). Since HMS placed or handled over 3,000 voice communications during the 1992 F2P2 in addition to the over 13,000 fax communications, it was readily apparent that no less than 3 unlisted lines are needed to run the program. On 20 of the 29 MESSAGE days, HMS was forced to use normal business lines, in addition to the three F2P2 lines, to meet user requirements. While it is hoped that the inclusion of Broadcast Fax will ease the phone line overloads, HMS identifies the need for at least three lines for the 1993 program instead of one line.

HMS utilizes a UDFCD transportable cellular phone within the F2P2 for several purposes. Most importantly, it allows an HMS meteorologist to provide direct storm observations by vehicle. Each year, mobile observation is made by HMS of 10-15 storms. Next, it allows the HMS meteorologist to leave the weather center and make direct observation of storms from the HMS roof-top observation site while still manning program phones. This process occurs on most MESSAGE days several times and facilitates invaluable observation input.

The original transportable phone was purchased by UDFCD in the mid 1980's, and was a very progressive step at the time. However, cellular phone technology has passed the old phone by. Two factors are especially important, connectability issues and unit weight. The old phone tips the scales at over eight pounds and relies on obsolescent battery technology. This weight factor discourages the use of the phone.

More importantly, connectability and battery technology issues are developing. The current battery in the UDFCD phone decreases the field flexibility of the phone, and constrains the use time between charges. There is no connectability between the UDFCD phone and laptop computers.

Training Concerns

- User understanding of F2P2 products and their utility in flood warning programs continued to be a concern.

HMS noted a continuing need for training of both dispatchers and other emergency response personnel in the understanding and utilization of F2P2 products within Flood Warning Plans and in emergency situations. These factors have become apparent when working with dispatchers and other emergency response personnel on message days during the 1990, 1991, and 1992 F2P2 seasons. It is obvious that even if a flood forecast is perfect and the flooding rainfall and stream flow are measured that a system failure could still result by an ineffectively carried out plan or poor communication.

Recommendations

1. HMS recommends that the 1993 F2P2 program adopts the new US WEST Broadcast Fax service as a potential source of eliminating the fax "log jam" problem. The Broadcast Fax service allows the user to disseminate a fax to multiple locations simultaneously, therefore greatly reducing the time needed to reach all F2P2 users. This service would also reach all users at the same time, eliminating any concern over which user should receive the fax first or if a specific user has in deed received the fax.

2. HMS recommends that the UDFCD include the three unlisted telephone lines as a requirement for the F2P2, and add the cost of those lines into its funding.

3. HMS recommends that it purchase its own cellular phone and charge back to the F2P2 program the fees for all calls related to the F2P2 program during the next season that HMS participates in. Today's cellular phones are very lightweight with most phones weighing less than two pounds. Newer battery technology will increase the use time of the phone by several factors of time. Additionally, the opportunity to connect a laptop computer to a cellular phone through a modem will allow HMS to connect a laptop to its existing ALERT base station during storms to enhance support to users under severe conditions.

4. HMS recommends that an expanded F2P2 training program be developed cooperatively between the District and HMS. The training program would encompass the following elements.

    - The development and implementation of effective, seasonal flash flood exercises in each of the District warning plan basins.

    - Training in the proper utilization of ALERT base stations

    - The development of effective flood warning systems, plans, and communications.

    - The development of a training session to increase the understanding of the F2P2 products.

    HMS would welcome the opportunity to develop this enhanced F2P2 training program which addresses these needs with the District. We will address this program in more detail in a separate proposal to the District.

APPENDIX A

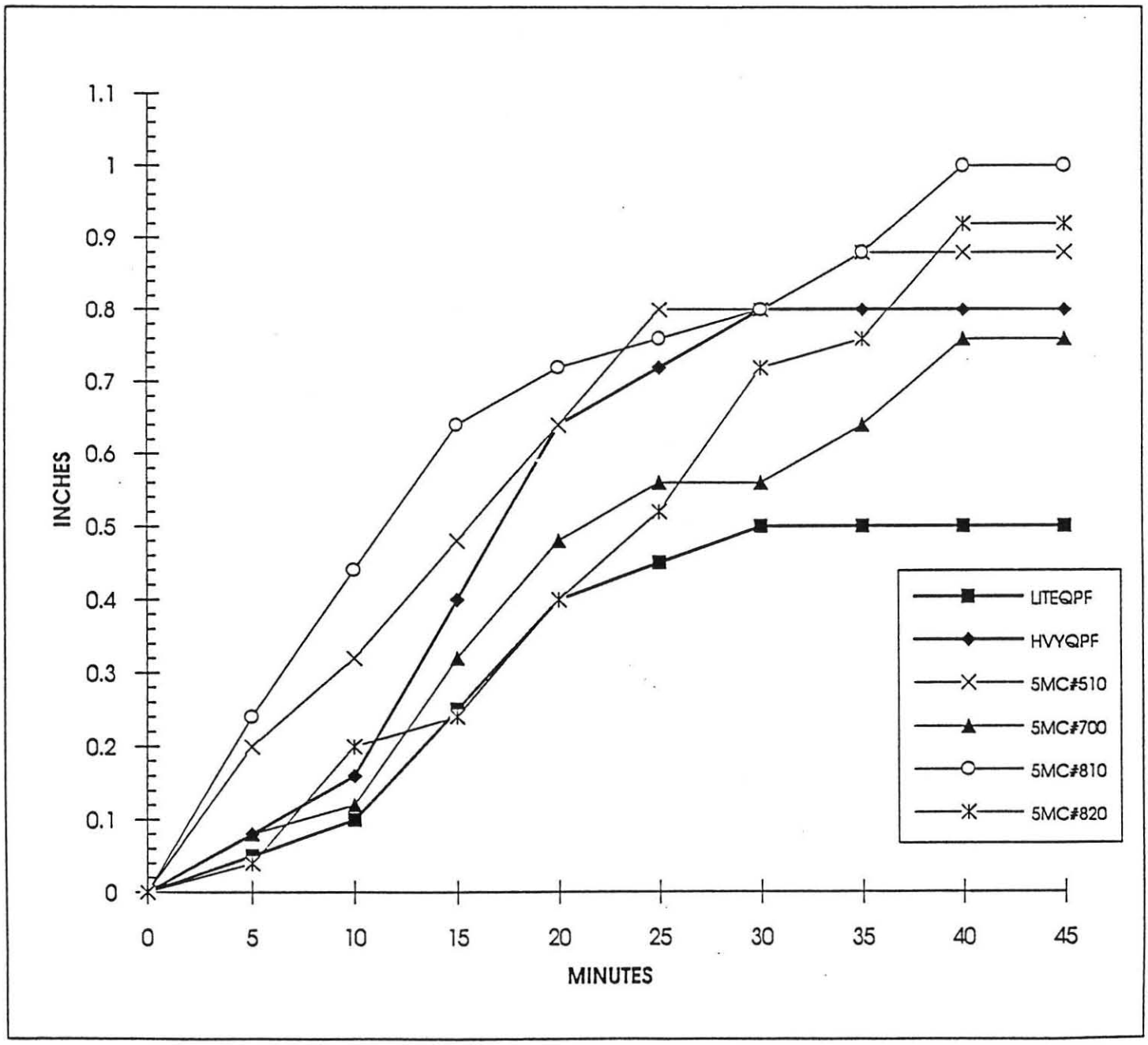
Examples of Quantitative Precipitation Forecast (QPF) Verification Versus Observed Rainfall for the 1992 Season

Rainfall Dates:

June 6, 1992
June 8, 1992
June 19, 1992
June 25, 1992
July 12, 1992
July 15, 1992
July 23, 1992
July 26, 1992
August 12, 1992
August 23, 1992
August 24, 1992

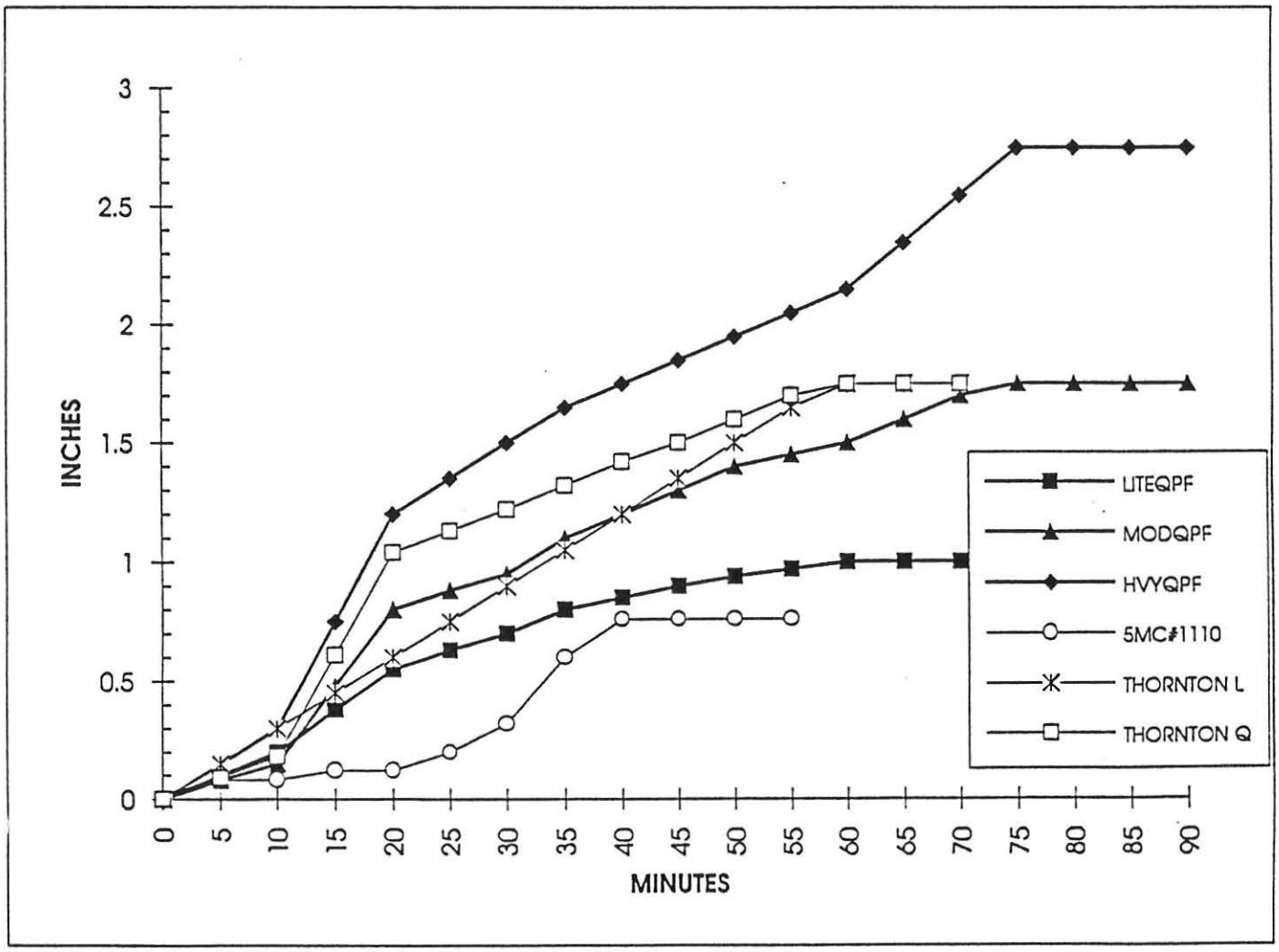
JUNE 6, 1992 THUNDERSTORM (1656 - 1739 L)
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	HVYQPF	5M#510	5MC#510	5M#700	5MC#700	5M#810	5MC#810	5M#820	5MC#820
0	0	0	0	0	0	0	0	0	0	0
5	0.05	0.08	0.20	0.20	0.08	0.08	0.24	0.24	0.04	0.04
10	0.10	0.16	0.12	0.32	0.04	0.12	0.20	0.44	0.16	0.20
15	0.25	0.40	0.16	0.48	0.20	0.32	0.20	0.64	0.04	0.24
20	0.40	0.64	0.16	0.64	0.16	0.48	0.08	0.72	0.16	0.40
25	0.45	0.72	0.16	0.80	0.08	0.56	0.04	0.76	0.12	0.52
30	0.50	0.80	0.00	0.80	0.00	0.56	0.04	0.80	0.20	0.72
35	0.50	0.80	0.08	0.88	0.08	0.64	0.08	0.88	0.04	0.76
40	0.50	0.80	0.00	0.88	0.12	0.76	0.12	1.00	0.16	0.92
45	0.50	0.80	0.00	0.88	0.00	0.76	0.00	1.00	0.00	0.92



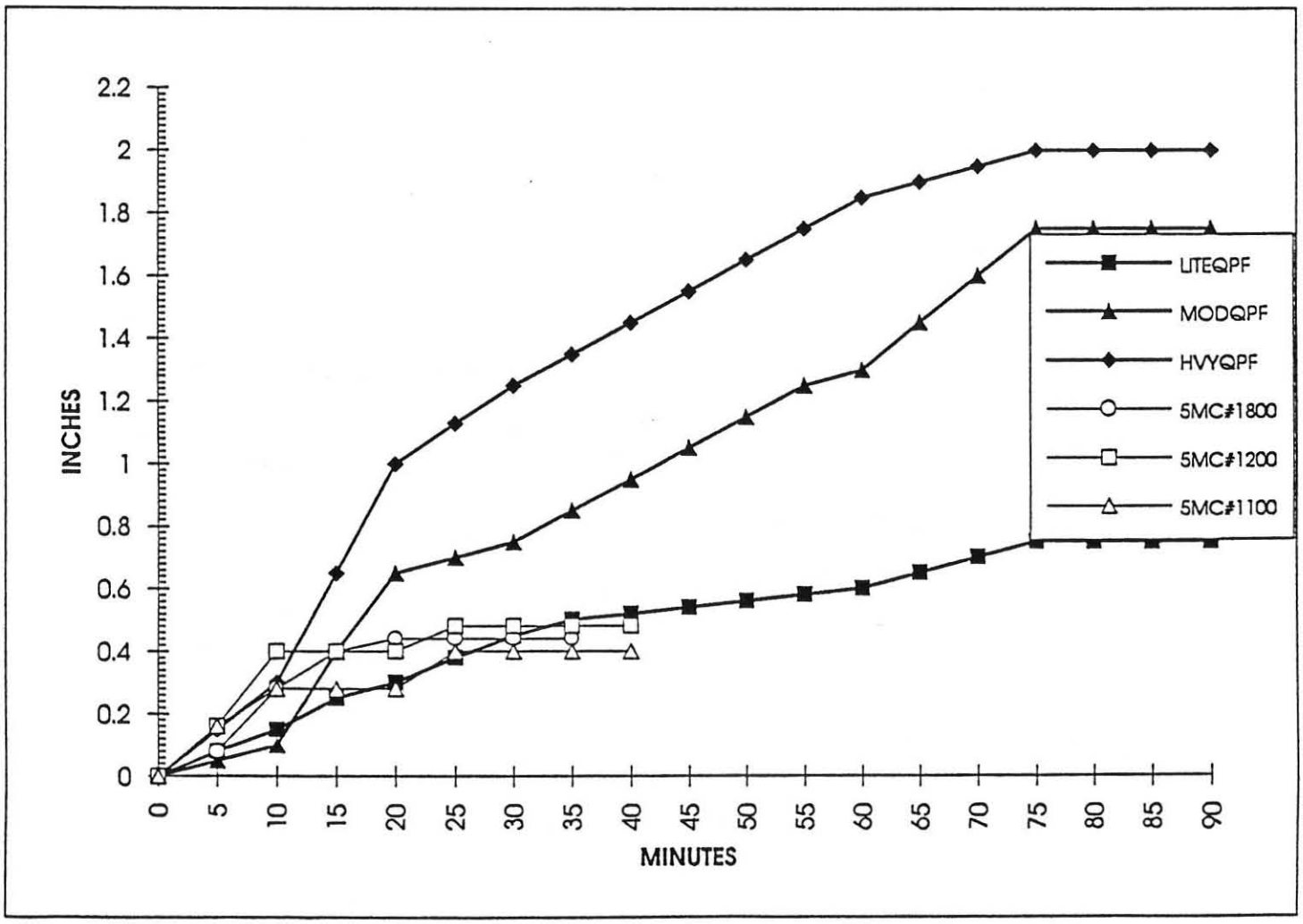
JUNE 8, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5M#1110	5MC#1110	THORNTON L	THORNTON Q
0	0	0	0	0	0	0	0
5	0.10	0.08	0.15	0.08	0.08	0.15	0.09
10	0.20	0.15	0.30	0.00	0.08	0.30	0.18
15	0.38	0.48	0.75	0.04	0.12	0.45	0.61
20	0.55	0.80	1.20	0.00	0.12	0.60	1.04
25	0.63	0.88	1.35	0.08	0.20	0.75	1.13
30	0.70	0.95	1.50	0.12	0.32	0.90	1.22
35	0.80	1.10	1.65	0.28	0.60	1.05	1.32
40	0.85	1.20	1.75	0.16	0.76	1.20	1.42
45	0.90	1.30	1.85	0.00	0.76	1.35	1.50
50	0.94	1.40	1.95	0.00	0.76	1.50	1.60
55	0.97	1.45	2.05	0.00	0.76	1.65	1.70
60	1.00	1.50	2.15			1.75	1.75
65	1.00	1.60	2.35			1.75	1.75
70	1.00	1.70	2.55			1.75	1.75
75	1.00	1.75	2.75				
80	1.00	1.75	2.75				
85	1.00	1.75	2.75				
90	1.00	1.75	2.75				



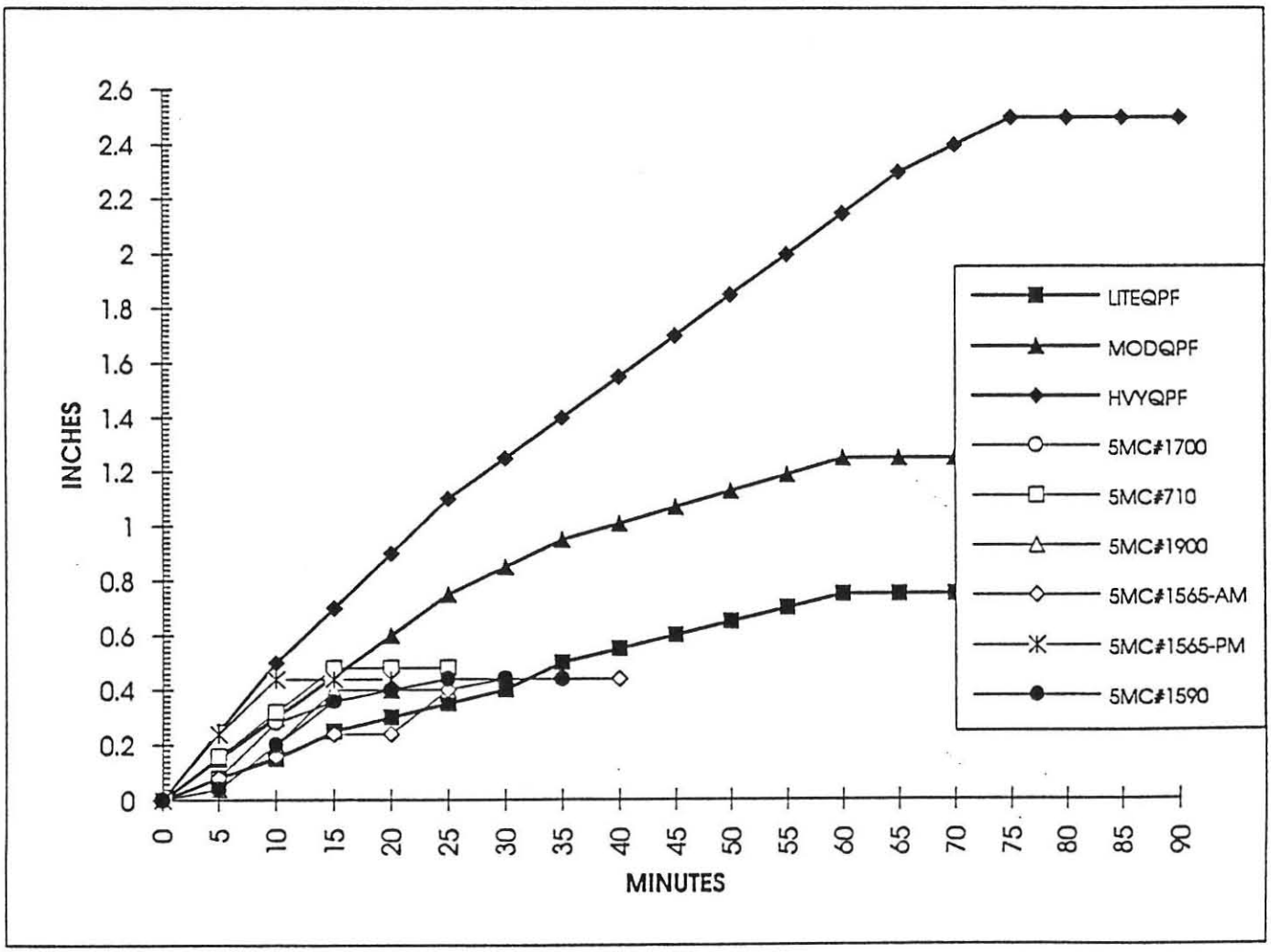
JUNE 19, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5M#1800	5MC#1800	5M#1200	5MC#1200	5M#1100	5MC#1100
0	0	0	0	0	0	0	0	0	0
5	0.08	0.05	0.15	0.08	0.08	0.16	0.16	0.16	0.16
10	0.15	0.10	0.30	0.20	0.28	0.24	0.40	0.12	0.28
15	0.25	0.40	0.65	0.12	0.40	0.00	0.40	0.00	0.28
20	0.30	0.65	1.00	0.04	0.44	0.00	0.40	0.00	0.28
25	0.38	0.70	1.13	0.00	0.44	0.08	0.48	0.12	0.40
30	0.45	0.75	1.25	0.00	0.44	0.00	0.48	0.00	0.40
35	0.50	0.85	1.35	0.00	0.44	0.00	0.48	0.00	0.40
40	0.52	0.95	1.45			0.00	0.48	0.00	0.40
45	0.54	1.05	1.55						
50	0.56	1.15	1.65						
55	0.58	1.25	1.75						
60	0.60	1.30	1.85						
65	0.65	1.45	1.90						
70	0.70	1.60	1.95						
75	0.75	1.75	2.00						
80	0.75	1.75	2.00						
85	0.75	1.75	2.00						
90	0.75	1.75	2.00						



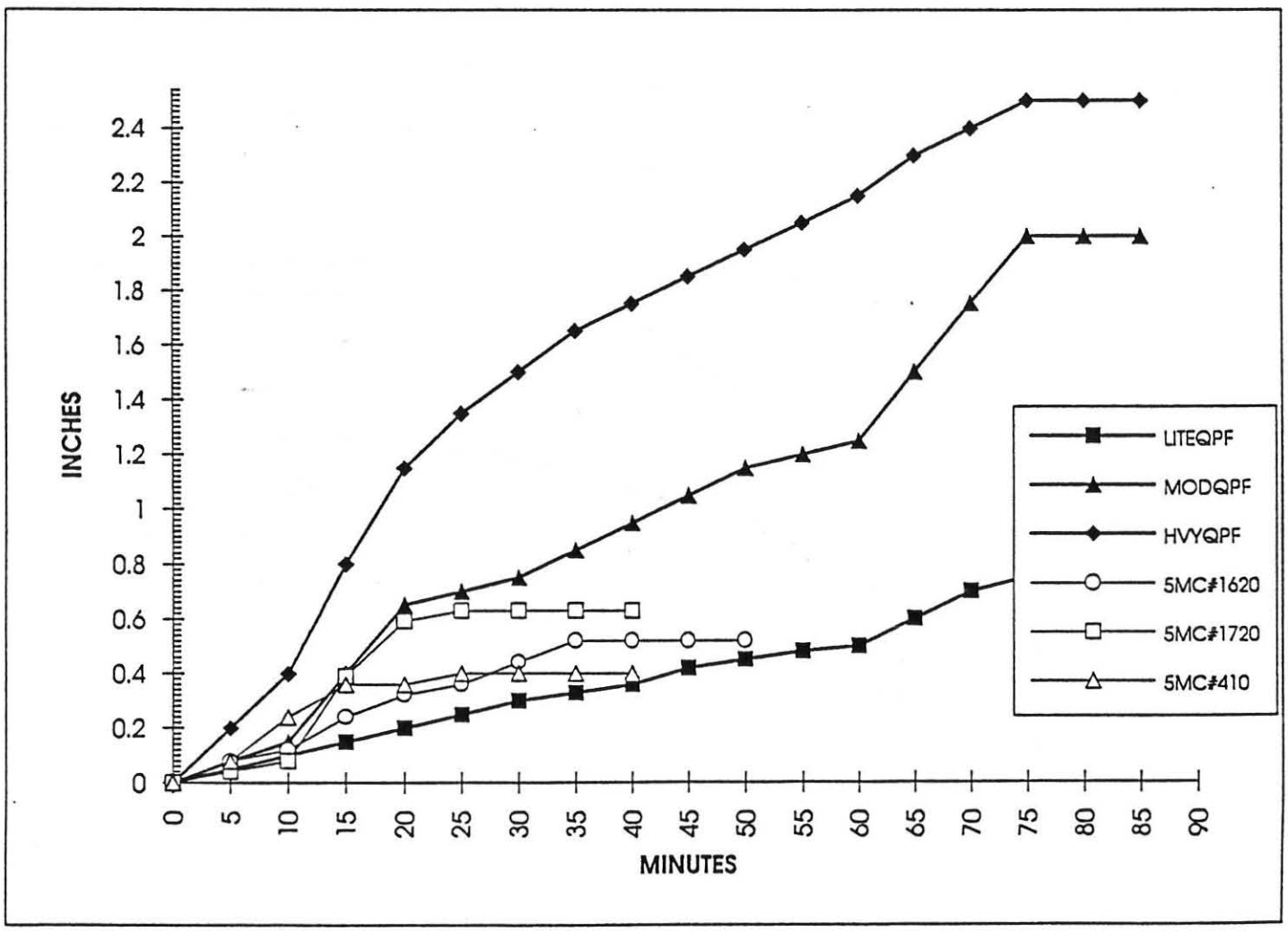
JUNE 25, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5MC#1700	5MC#710	5MC#1900	5MC#1565-AM	5MC#1565-PM	5MC#1590
0	0	0	0	0	0	0	0	0	0
5	0.08	0.15	0.25	0.08	0.16	0.04	0.08	0.24	0.04
10	0.15	0.30	0.50	0.28	0.32	0.20	0.16	0.44	0.20
15	0.25	0.45	0.70	0.36	0.48	0.40	0.24	0.44	0.36
20	0.30	0.60	0.90	0.40	0.48	0.40	0.24	0.44	0.40
25	0.35	0.75	1.10	0.44	0.48	0.40	0.40		0.44
30	0.40	0.85	1.25	0.44			0.44		0.44
35	0.50	0.95	1.40	0.44			0.44		0.44
40	0.55	1.01	1.55				0.44		
45	0.60	1.07	1.70						
50	0.65	1.13	1.85						
55	0.70	1.19	2.00						
60	0.75	1.25	2.15						
65	0.75	1.25	2.30						
70	0.75	1.25	2.40						
75	0.75	1.25	2.50						
80			2.50						
85			2.50						
90			2.50						



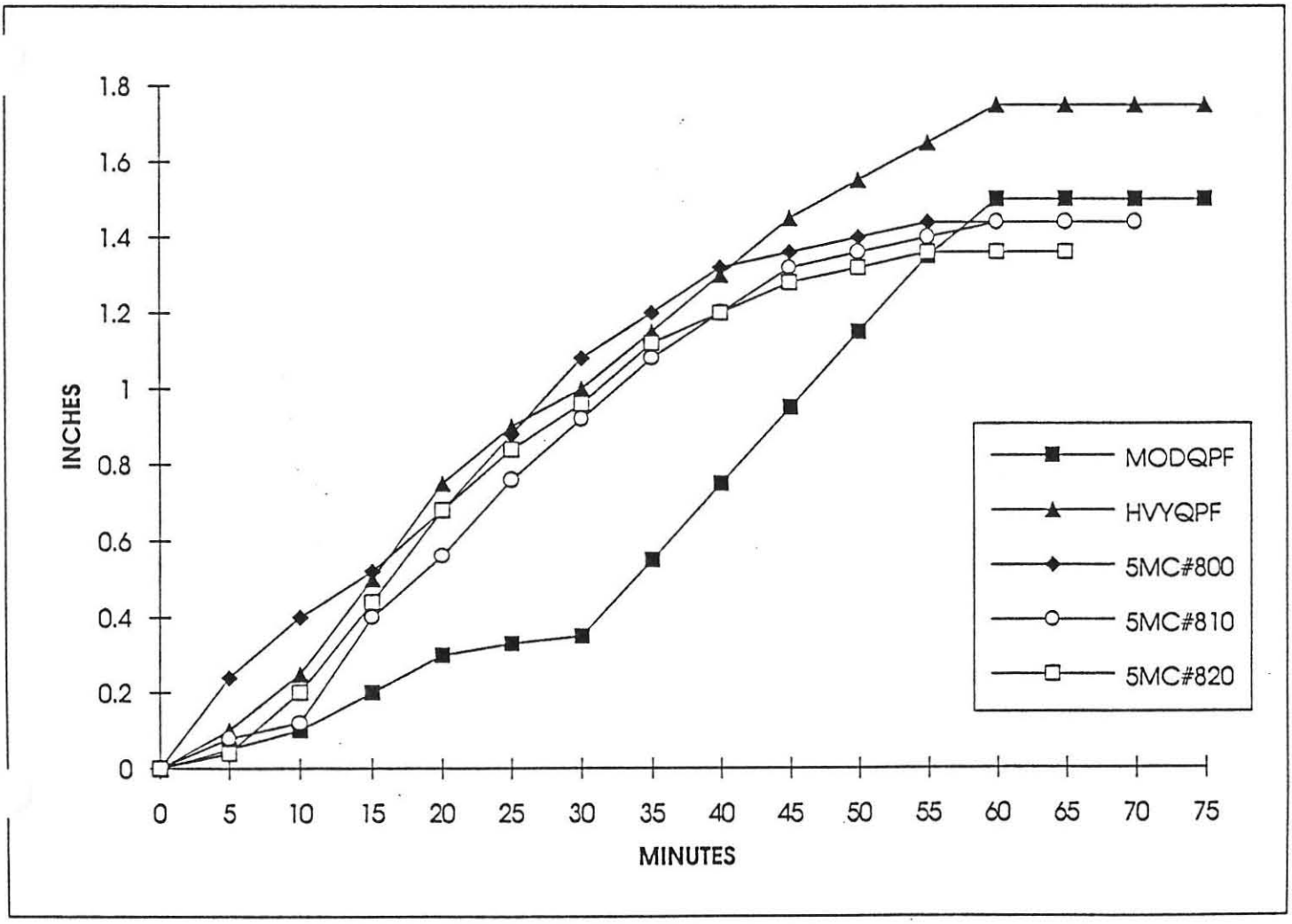
JULY 12, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5M#1620	5MC#1620	5M#1720	5MC#1720	5M#410	5MC#410
0	0	0	0	0	0	0	0	0	0
5	0.05	0.08	0.20	0.08	0.08	0.04	0.04	0.08	0.08
10	0.10	0.15	0.40	0.04	0.12	0.04	0.08	0.16	0.24
15	0.15	0.40	0.80	0.12	0.24	0.31	0.39	0.12	0.36
20	0.20	0.65	1.15	0.08	0.32	0.20	0.59	0.00	0.36
25	0.25	0.70	1.35	0.04	0.36	0.04	0.63	0.04	0.40
30	0.30	0.75	1.50	0.08	0.44	0.00	0.63	0.00	0.40
35	0.33	0.85	1.65	0.08	0.52	0.00	0.63	0.00	0.40
40	0.36	0.95	1.75	0.00	0.52	0.00	0.63	0.00	0.40
45	0.42	1.05	1.85	0.00	0.52				
50	0.45	1.15	1.95	0.00	0.52				
55	0.48	1.20	2.05						
60	0.50	1.25	2.15						
65	0.60	1.50	2.30						
70	0.70	1.75	2.40						
75	0.75	2.00	2.50						
80	0.75	2.00	2.50						
85	0.75	2.00	2.50						
90									



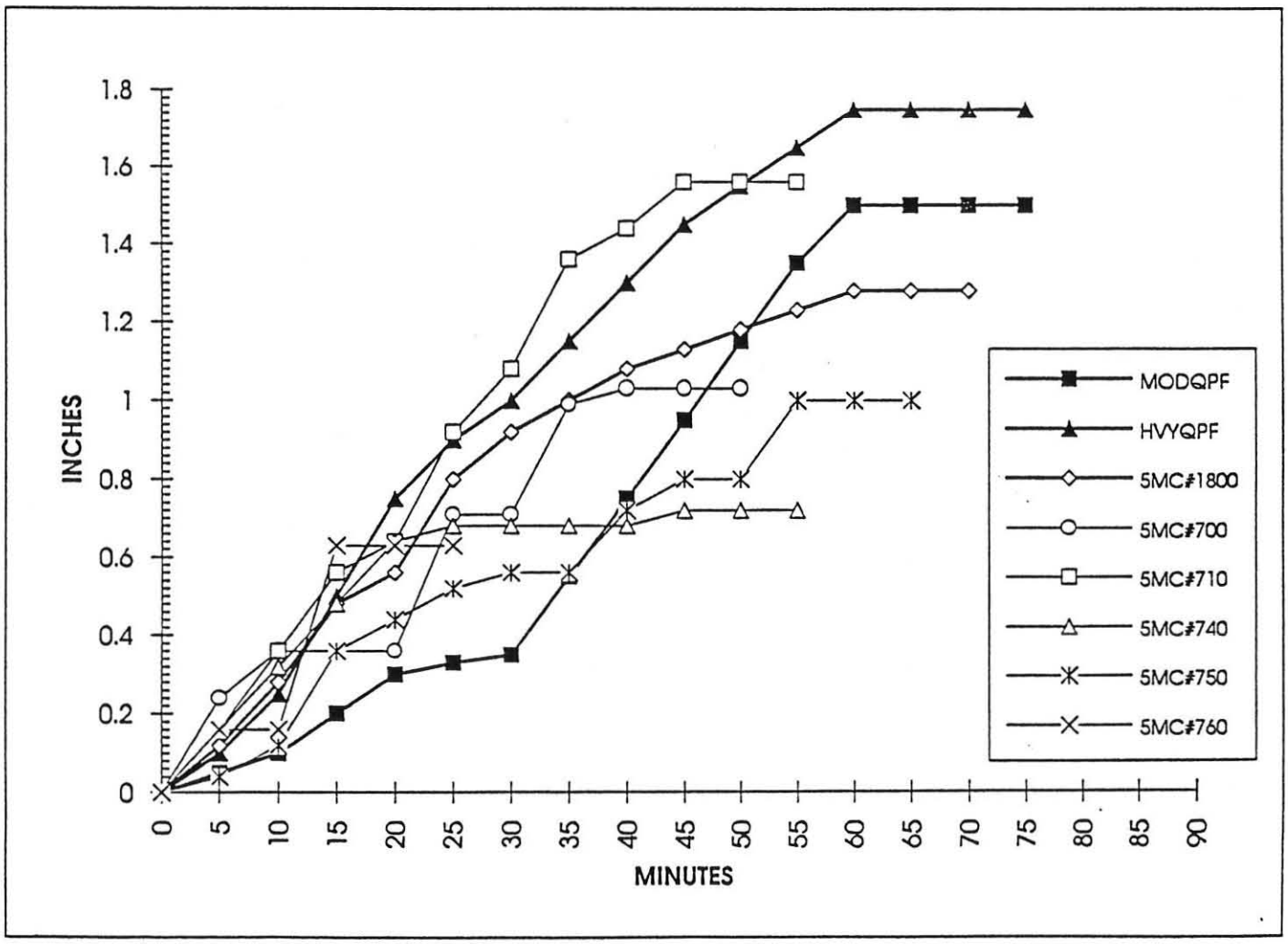
JULY 15, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	MODQPF	HVYQPF	5M#800	5MC#800	5M#810	5MC#810	5M#820	5MC#820
0	0	0	0	0	0	0	0	0
5	0.05	0.10	0.24	0.24	0.08	0.08	0.04	0.04
10	0.10	0.25	0.16	0.40	0.04	0.12	0.16	0.20
15	0.20	0.50	0.12	0.52	0.28	0.40	0.24	0.44
20	0.30	0.75	0.16	0.68	0.16	0.56	0.24	0.68
25	0.33	0.90	0.20	0.88	0.20	0.76	0.16	0.84
30	0.35	1.00	0.20	1.08	0.16	0.92	0.12	0.96
35	0.55	1.15	0.12	1.20	0.16	1.08	0.16	1.12
40	0.75	1.30	0.12	1.32	0.12	1.20	0.08	1.20
45	0.95	1.45	0.04	1.36	0.12	1.32	0.08	1.28
50	1.15	1.55	0.04	1.40	0.04	1.36	0.04	1.32
55	1.35	1.65	0.04	1.44	0.04	1.40	0.04	1.36
60	1.50	1.75	0.00	1.44	0.04	1.44	0.00	1.36
65	1.50	1.75	0.00	1.44	0.00	1.44	0.00	1.36
70	1.50	1.75			0.00	1.44		
75	1.50	1.75						
80								
85								
90								



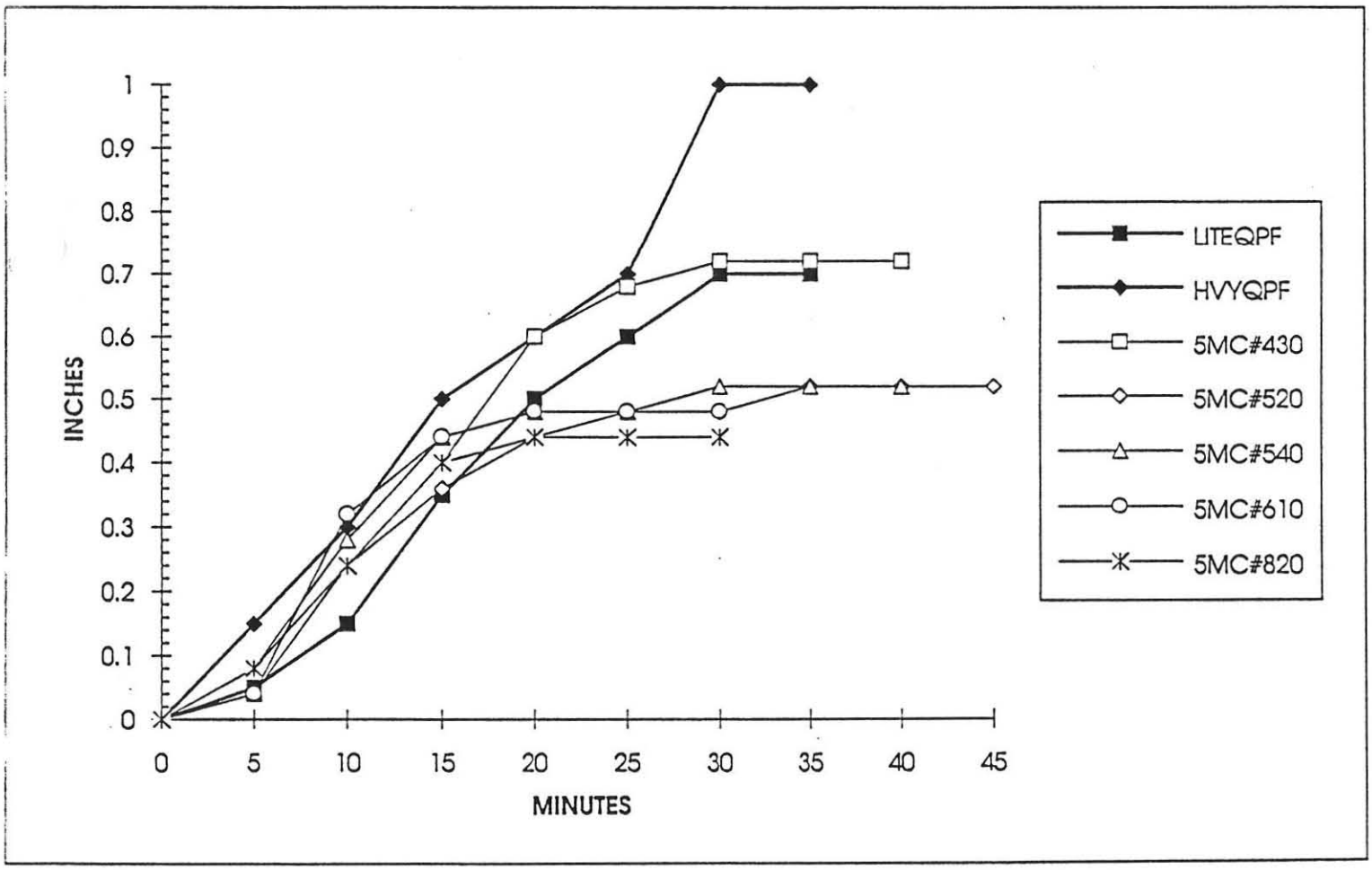
JULY 15, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	MODQPF	HVYQPF	5MC#1800	5MC#700	5MC#710	5MC#740	5MC#750	5MC#760
0	0	0	0	0	0	0	0	0
5	0.05	0.10	0.12	0.24	0.16	0.16	0.04	0.16
10	0.10	0.25	0.28	0.36	0.36	0.32	0.12	0.16
15	0.20	0.50	0.48	0.36	0.56	0.48	0.36	0.63
20	0.30	0.75	0.56	0.36	0.64	0.64	0.44	0.63
25	0.33	0.90	0.80	0.71	0.92	0.68	0.52	0.63
30	0.35	1.00	0.92	0.71	1.08	0.68	0.56	
35	0.55	1.15	1.00	0.99	1.36	0.68	0.56	
40	0.75	1.30	1.08	1.03	1.44	0.68	0.72	
45	0.95	1.45	1.13	1.03	1.56	0.72	0.80	
50	1.15	1.55	1.18	1.03	1.56	0.72	0.80	
55	1.35	1.65	1.23		1.56	0.72	1.00	
60	1.50	1.75	1.28				1.00	
65	1.50	1.75	1.28				1.00	
70	1.50	1.75	1.28					
75	1.50	1.75						
80								
85								
90								



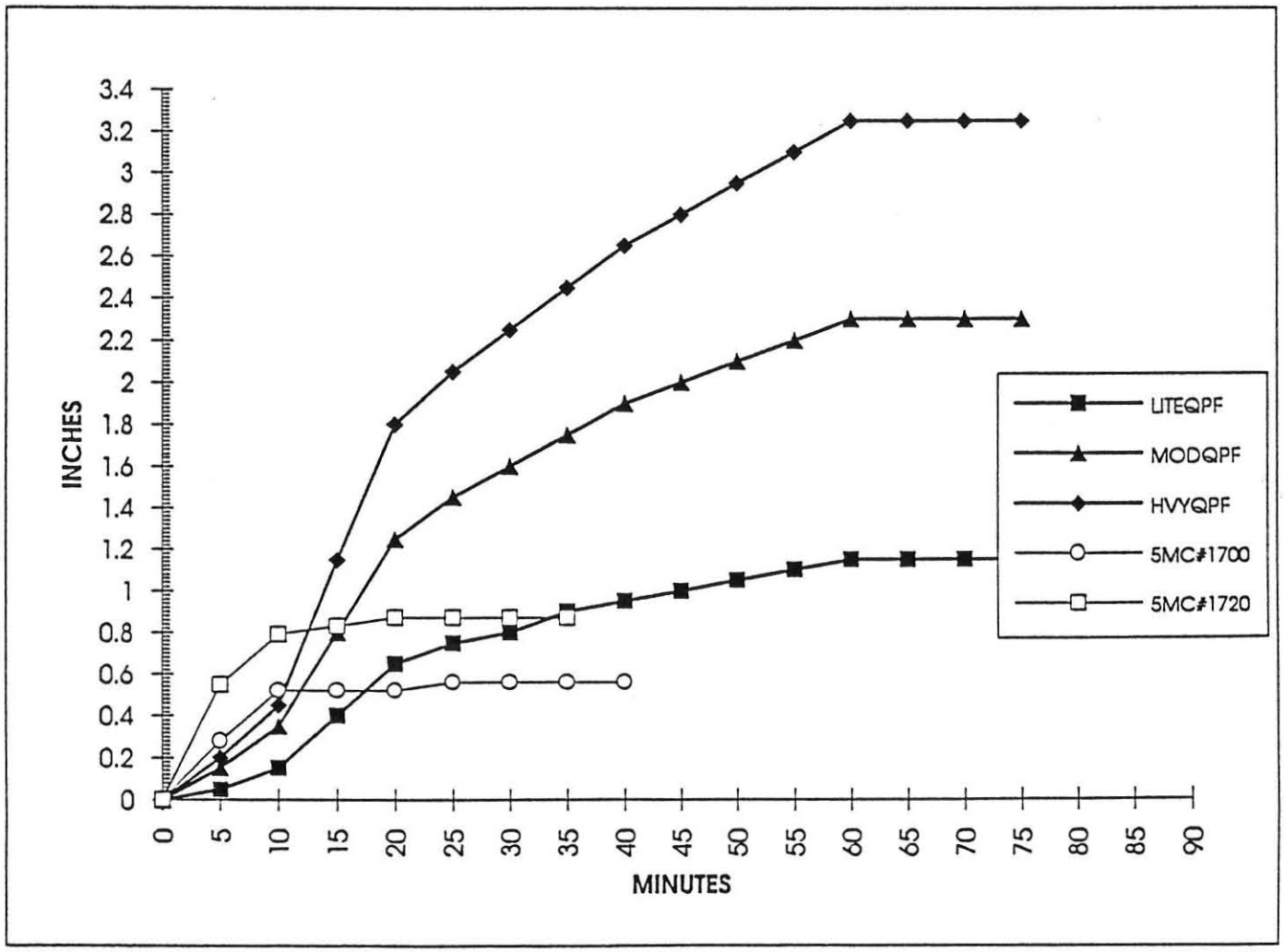
JULY 23, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

...METIME	LITEQPF	HVYQPF	5M#430	5MC#430	5M#520	5MC#520	5M#540	5MC#540	5M#610	5MC#610	5M#820	5MC#820
0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.05	0.15	0.04	0.04	0.08	0.08	0.08	0.08	0.04	0.04	0.08	0.08
10	0.15	0.30	0.20	0.24	0.16	0.24	0.20	0.28	0.28	0.32	0.16	0.24
15	0.35	0.50	0.16	0.40	0.12	0.36	0.16	0.44	0.12	0.44	0.16	0.40
20	0.50	0.60	0.20	0.60	0.08	0.44	0.04	0.48	0.04	0.48	0.04	0.44
25	0.60	0.70	0.08	0.68	0.04	0.48	0.00	0.48	0.00	0.48	0.00	0.44
30	0.70	1.00	0.04	0.72	0.00	0.48	0.04	0.52	0.00	0.48	0.00	0.44
35	0.70	1.00	0.00	0.72	0.04	0.52	0.00	0.52				
40			0.00	0.72	0.00	0.52	0.00	0.52				
45					0.00	0.52						



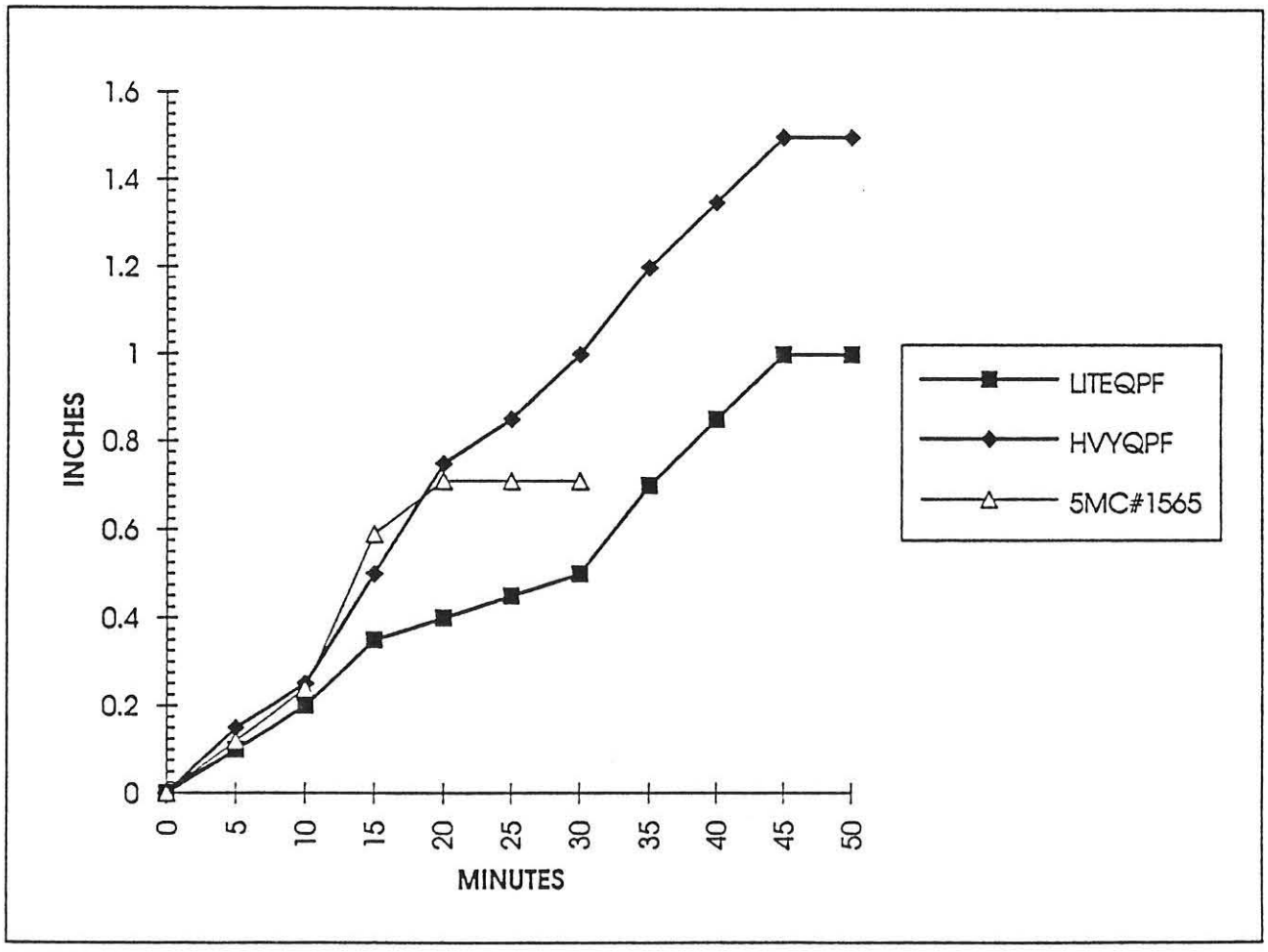
JULY 26, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	MODQPF	HVYQPF	5M#1700	5MC#1700	5M#1720	5MC#1720	
0	0	0	0	0	0	0	0	
5	0.05	0.15	0.20	0.28	0.28	0.55	0.55	
10	0.15	0.35	0.45	0.24	0.52	0.24	0.79	
15	0.40	0.80	1.15	0.00	0.52	0.04	0.83	
20	0.65	1.25	1.80	0.00	0.52	0.04	0.87	
25	0.75	1.45	2.05	0.04	0.56	0.00	0.87	
30	0.80	1.60	2.25	0.00	0.56	0.00	0.87	
35	0.90	1.75	2.45	0.00	0.56	0.00	0.87	
40	0.95	1.90	2.65	0.00	0.56			
45	1.00	2.00	2.80					
50	1.05	2.10	2.95					
55	1.10	2.20	3.10					
60	1.15	2.30	3.25					
65	1.15	2.30	3.25					
70	1.15	2.30	3.25					
75	1.15	2.30	3.25					
80								
85								
90								



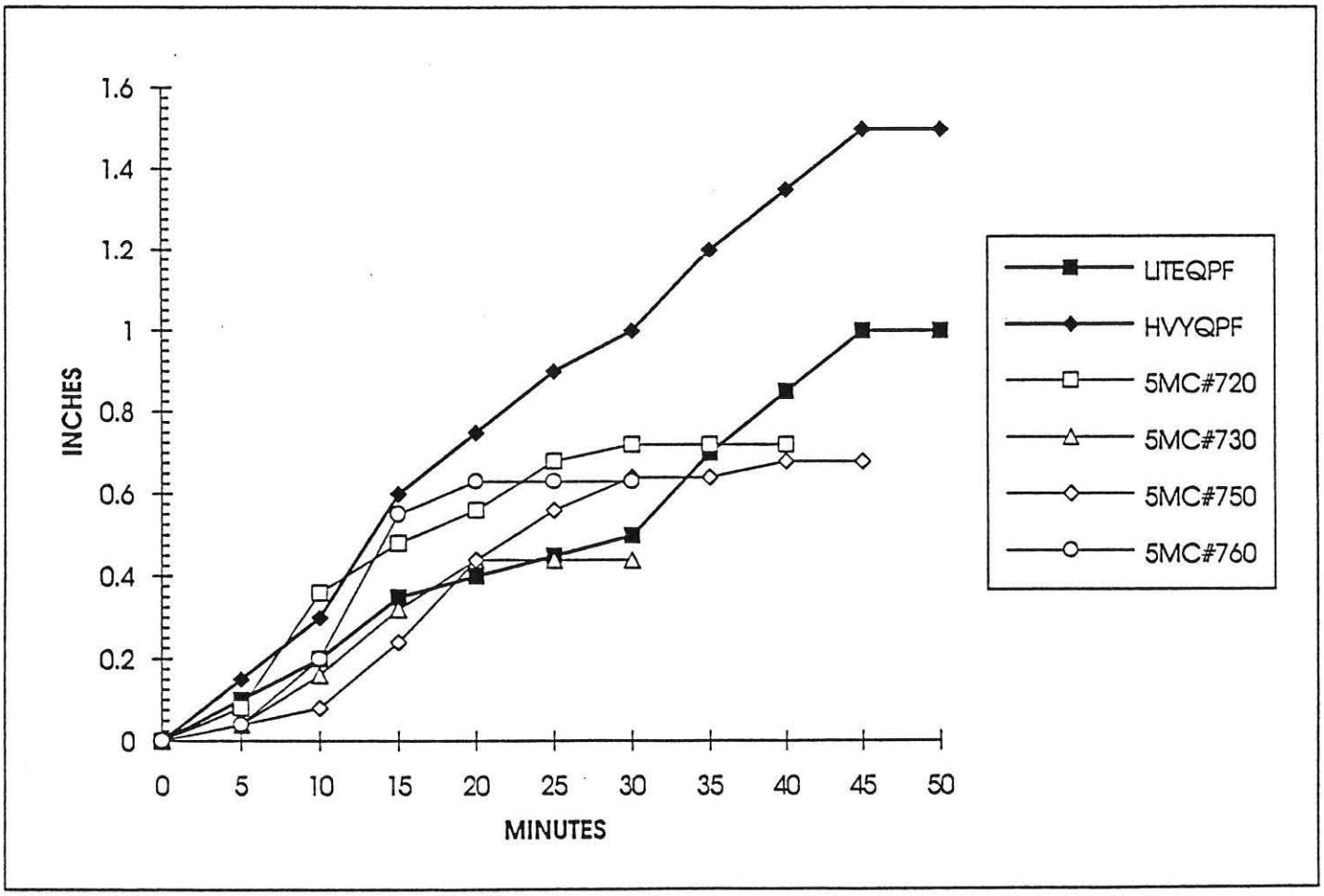
AUGUST 12, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	HVYQPF	5M#1565	5MC#1565		
0	0	0	0	0		
5	0.10	0.15	0.12	0.12		
10	0.20	0.25	0.12	0.24		
15	0.35	0.50	0.35	0.59		
20	0.40	0.75	0.12	0.71		
25	0.45	0.85	0.00	0.71		
30	0.50	1.00	0.00	0.71		
35	0.70	1.20				
40	0.85	1.35				
45	1.00	1.50				
50	1.00	1.50				



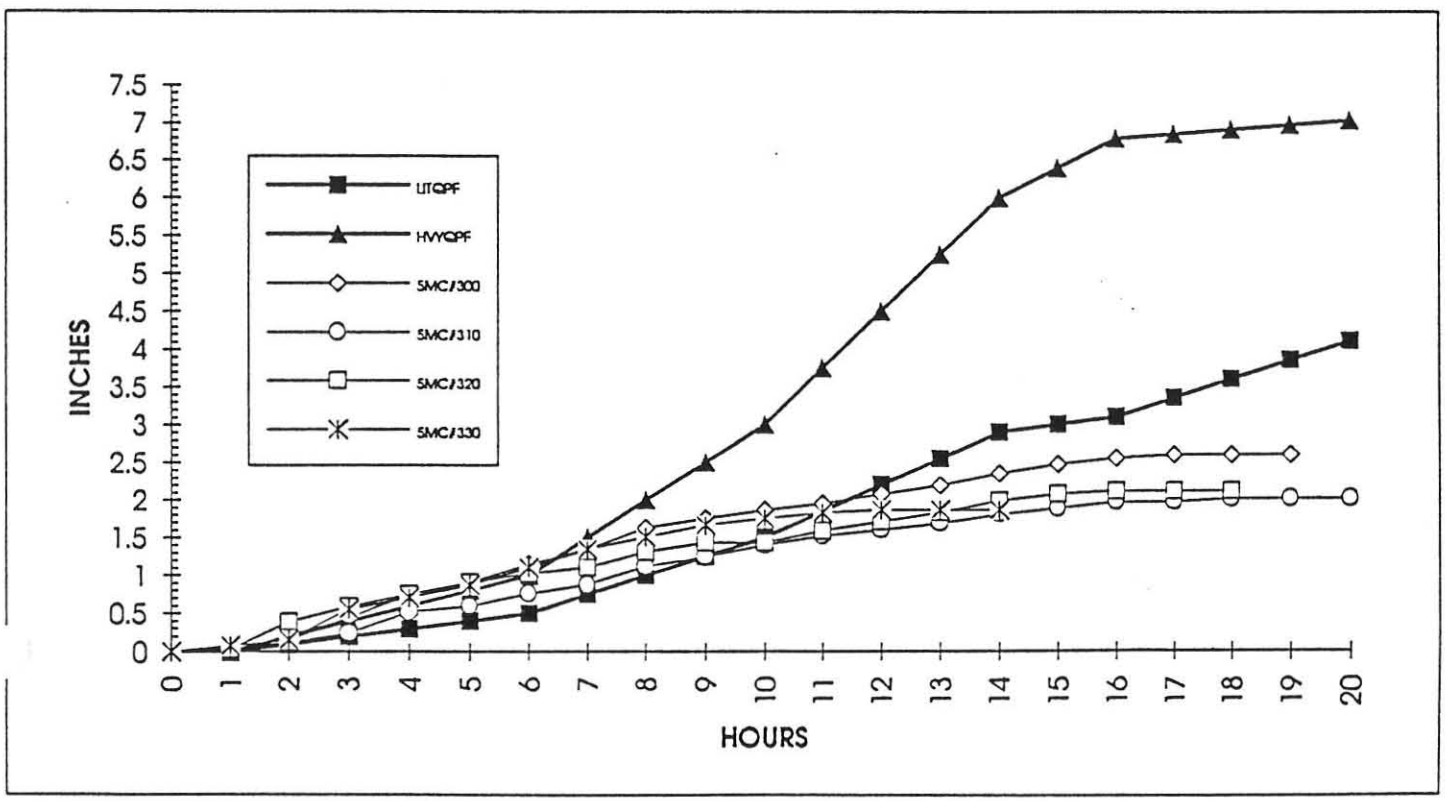
AUGUST 23, 1992 THUNDERSTORM
QPF VERSUS OBSERVED RAINFALL

CUMETIME	LITEQPF	HVYQPF	5M#720	5MC#720	5M#730	5MC#730	5M#750	5MC#750	5M#760	5MC#760
0	0	0	0	0	0	0	0	0	0	0
5	0.10	0.15	0.08	0.08	0.04	0.04	0.04	0.04	0.04	0.04
10	0.20	0.30	0.28	0.36	0.12	0.16	0.04	0.08	0.16	0.20
15	0.35	0.60	0.12	0.48	0.16	0.32	0.16	0.24	0.35	0.55
20	0.40	0.75	0.08	0.56	0.12	0.44	0.20	0.44	0.08	0.63
25	0.45	0.90	0.12	0.68	0.00	0.44	0.12	0.56	0.00	0.63
30	0.50	1.00	0.04	0.72	0.00	0.44	0.08	0.64	0.00	0.63
35	0.70	1.20	0.00	0.72			0.00	0.64		
40	0.85	1.35	0.00	0.72			0.04	0.68		
45	1.00	1.50					0.00	0.68		
50	1.00	1.50								



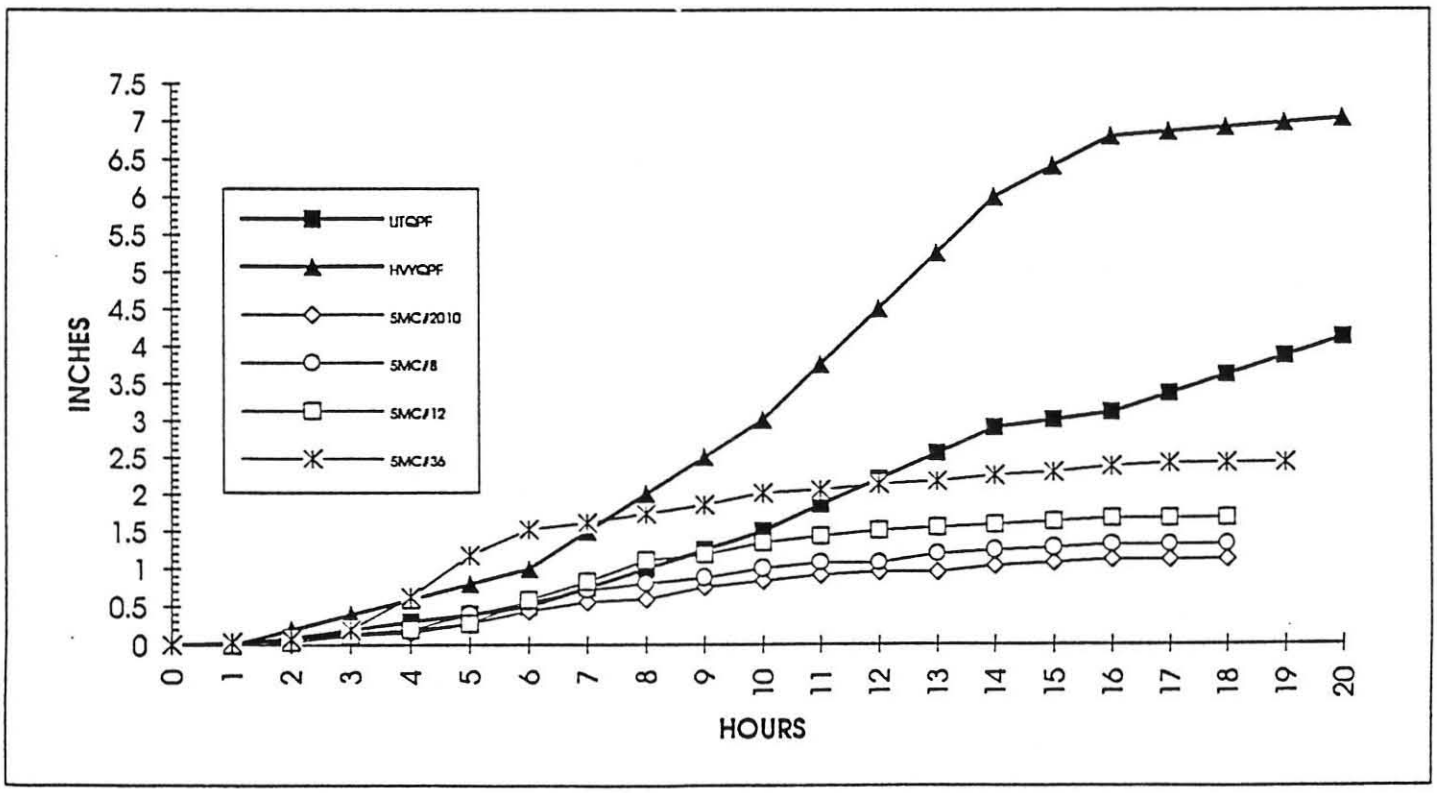
AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
VAN BIBBER CREEK

CUMETIME	LITQPF	HVYQPF	5MC#300	5MC#310	5MC#320	5MC#330
0	0	0	0	0	0	0
1	0	0	0.08	0.04	0.04	0.08
2	0.10	0.20	0.16	0.12	0.39	0.16
3	0.20	0.40	0.44	0.24	0.59	0.55
4	0.30	0.60	0.75	0.52	0.75	0.71
5	0.40	0.80	0.91	0.60	0.91	0.87
6	0.50	1.00	1.15	0.76	1.03	1.11
7	0.75	1.50	1.35	0.88	1.11	1.35
8	1.00	2.00	1.63	1.12	1.31	1.51
9	1.25	2.50	1.75	1.24	1.43	1.67
10	1.50	3.00	1.87	1.40	1.43	1.75
11	1.85	3.75	1.95	1.52	1.59	1.83
12	2.20	4.50	2.07	1.60	1.71	1.87
13	2.55	5.25	2.19	1.68	1.83	1.87
14	2.90	6.00	2.35	1.80	1.99	1.87
15	3.00	6.40	2.47	1.88	2.07	
16	3.10	6.80	2.55	1.96	2.11	
17	3.35	6.86	2.59	1.96	2.11	
18	3.60	6.92	2.59	2.00	2.11	
19	3.85	6.98	2.59	2.00		
20	4.10	7.04		2.00		
21	4.35	7.10				
22	4.60	7.16				
23	4.64	7.20				
24	4.68	7.24				



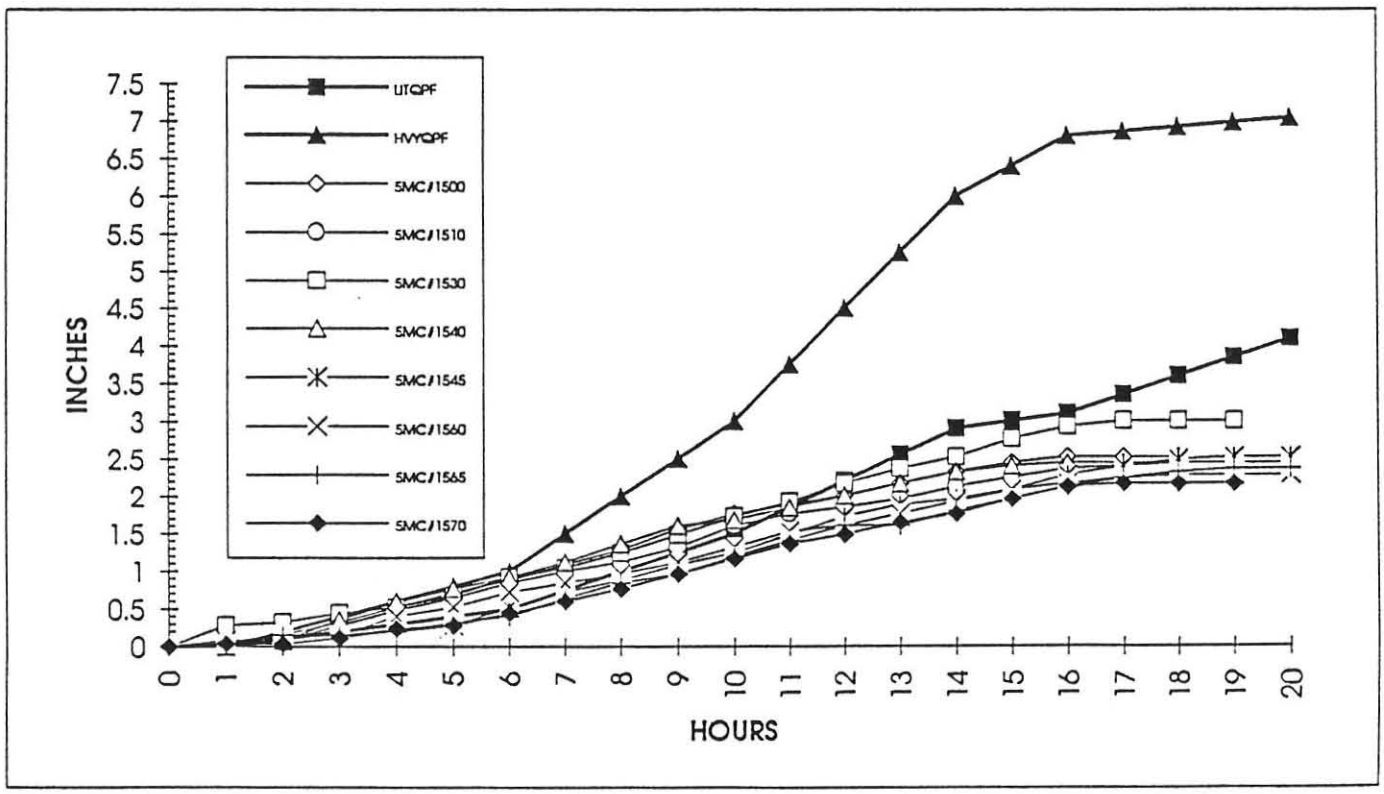
AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
BOULDER CREEK

CUMETIME	LITQPF	HVYQPF	5MC#2010	5MC#8	5MC#12	5MC#36
0	0	0	0	0	0	0
1	0	0	0.04	0.04	0.04	0.04
2	0.10	0.20	0.08	0.08	0.04	0.08
3	0.20	0.40	0.12	0.16	0.12	0.20
4	0.30	0.60	0.16	0.20	0.20	0.63
5	0.40	0.80	0.28	0.40	0.28	1.18
6	0.50	1.00	0.44	0.56	0.59	1.53
7	0.75	1.50	0.56	0.72	0.83	1.61
8	1.00	2.00	0.60	0.80	1.11	1.73
9	1.25	2.50	0.76	0.88	1.19	1.85
10	1.50	3.00	0.84	1.00	1.35	2.01
11	1.85	3.75	0.92	1.08	1.43	2.05
12	2.20	4.50	0.96	1.08	1.51	2.13
13	2.55	5.25	0.96	1.20	1.55	2.17
14	2.90	6.00	1.04	1.24	1.59	2.25
15	3.00	6.40	1.08	1.28	1.63	2.29
16	3.10	6.80	1.12	1.32	1.67	2.37
17	3.35	6.86	1.12	1.32	1.67	2.41
18	3.60	6.92	1.12	1.32	1.67	2.41
19	3.85	6.98				2.41
20	4.10	7.04				
21	4.35	7.10				
22	4.60	7.16				
23	4.64	7.20				
24	4.68	7.24				



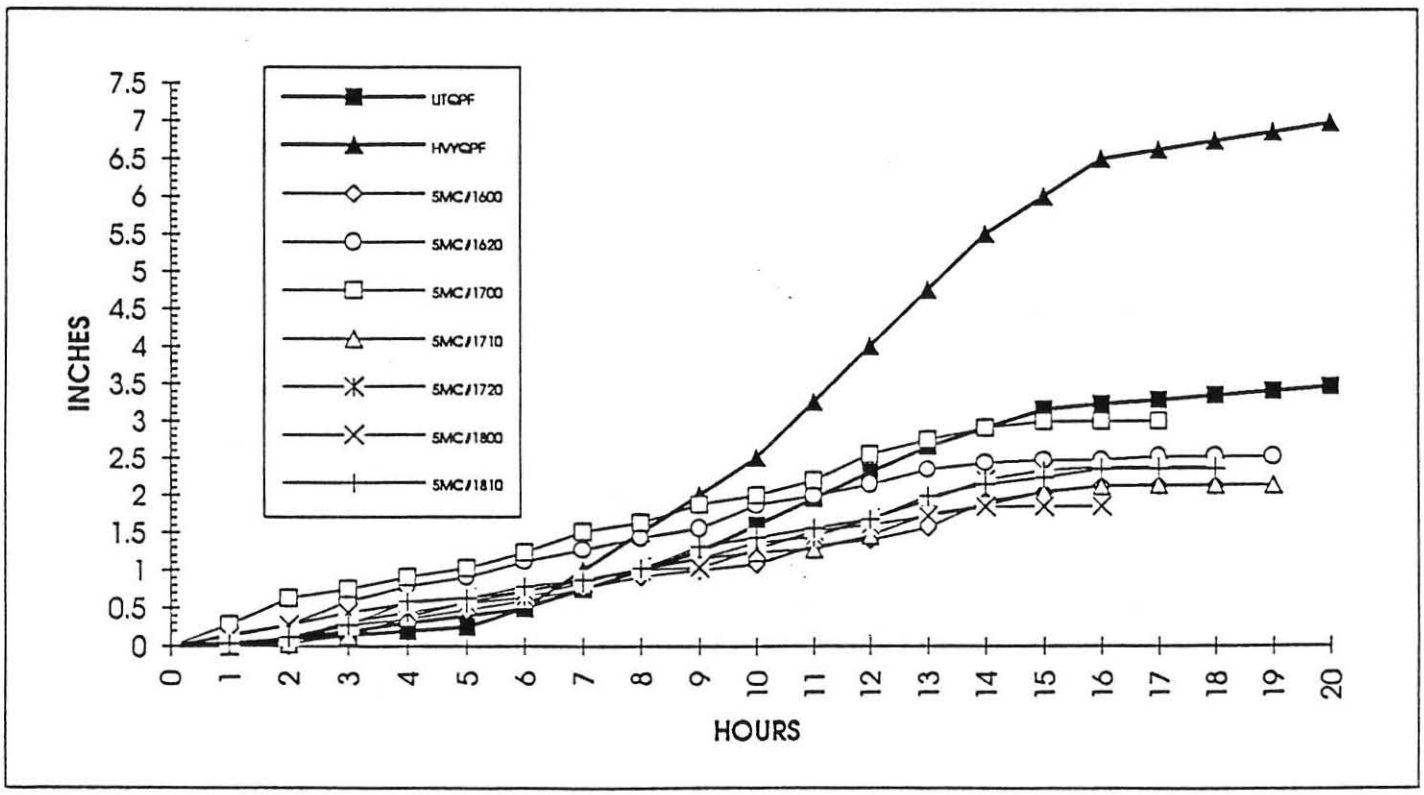
AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
BEAR CREEK

CUMETIME	LITQPF	HVYQPF	5MC#1500	5MC#1510	5MC#1530	5MC#1540	5MC#1545	5MC#1560	5MC#1565	5MC#1570
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0.04	0.04	0.28	0.08	0.08	0.08	0.04	0.04
2	0.10	0.20	0.16	0.08	0.32	0.08	0.12	0.12	0.16	0.04
3	0.20	0.40	0.32	0.28	0.44	0.36	0.16	0.16	0.16	0.12
4	0.30	0.60	0.52	0.48	0.52	0.60	0.20	0.40	0.20	0.24
5	0.40	0.80	0.72	0.64	0.68	0.76	0.28	0.52	0.32	0.28
6	0.50	1.00	0.88	0.84	0.92	0.92	0.52	0.72	0.40	0.44
7	0.75	1.50	1.08	1.00	1.04	1.12	0.72	0.84	0.64	0.60
8	1.00	2.00	1.28	1.12	1.24	1.36	0.88	0.96	0.84	0.76
9	1.25	2.50	1.56	1.32	1.48	1.60	1.08	1.12	0.96	0.96
10	1.50	3.00	1.76	1.60	1.72	1.68	1.24	1.32	1.20	1.16
11	1.85	3.75	1.88	1.76	1.92	1.84	1.48	1.52	1.40	1.36
12	2.20	4.50	2.00	1.84	2.16	2.00	1.72	1.60	1.60	1.48
13	2.55	5.25	2.16	1.96	2.36	2.16	1.88	1.76	1.60	1.64
14	2.90	6.00	2.32	2.12	2.52	2.32	1.96	1.92	1.80	1.76
15	3.00	6.40	2.44	2.24	2.76	2.40	2.08	2.08	1.96	1.96
16	3.10	6.80	2.52	2.36	2.92	2.44	2.28	2.16	2.12	2.12
17	3.35	6.86	2.52	2.40	3.00	2.44	2.40	2.24	2.24	2.16
18	3.60	6.92	2.52	2.44	3.00	2.44	2.48	2.28	2.32	2.16
19	3.85	6.98		2.44	3.00		2.52	2.28	2.36	2.16
20	4.10	7.04		2.44			2.52	2.28	2.36	
21	4.35	7.10								
22	4.60	7.16								
23	4.64	7.20								
24	4.68	7.24								



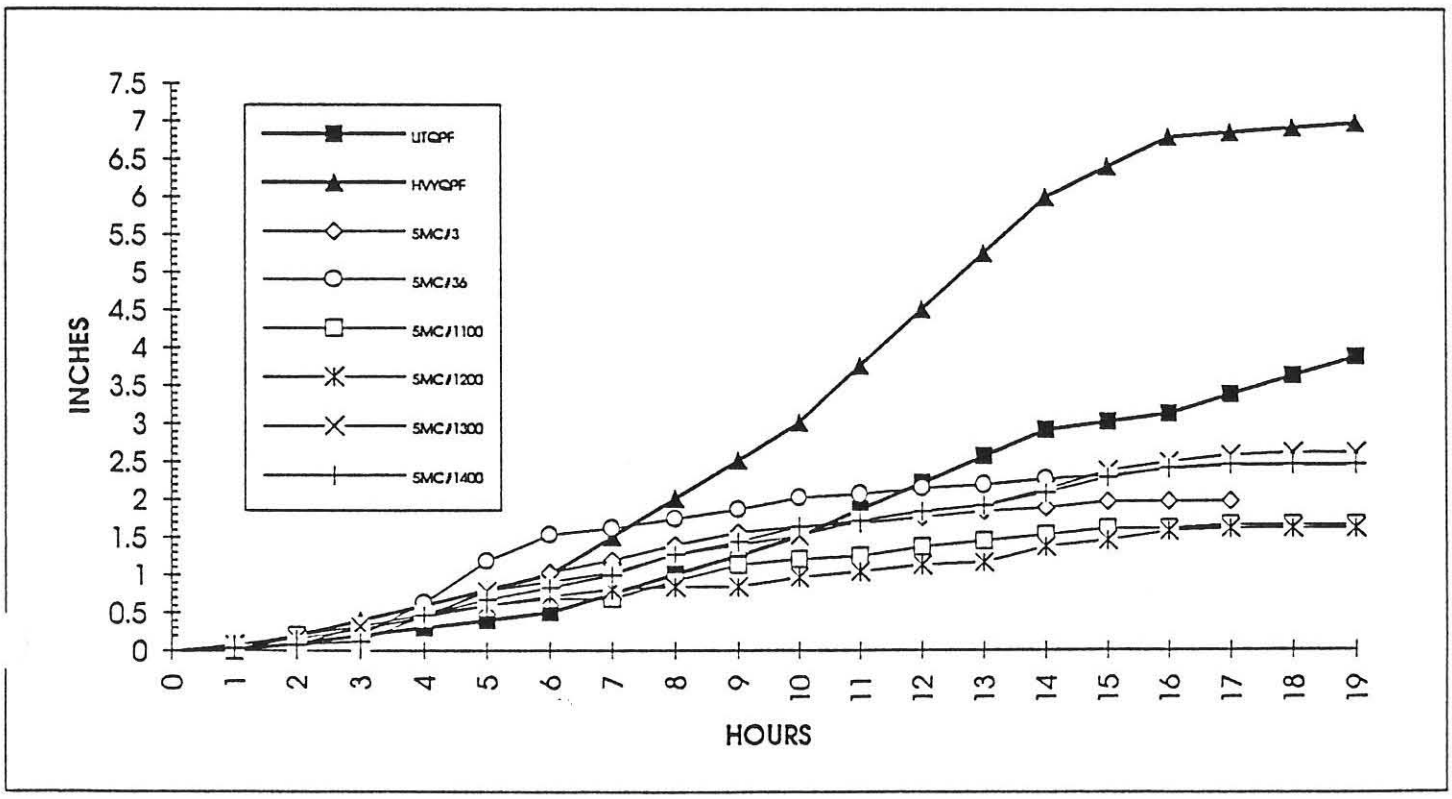
AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
DISTRICT WIDE - EAST

CUMETIME	LITQPF	HVYQPF	5MC#1600	5MC#1620	5MC#1700	5MC#1710	5MC#1720	5MC#1800	5MC#1810
0	0	0	0	0	0	0	0	0	0
1	0	0	0.04	0.16	0.28	0.01	0.04	0.12	0.04
2	0.05	0.10	0.08	0.28	0.63	0.04	0.12	0.28	0.12
3	0.10	0.20	0.28	0.59	0.75	0.14	0.32	0.44	0.28
4	0.15	0.30	0.36	0.79	0.91	0.38	0.44	0.56	0.59
5	0.20	0.40	0.48	0.91	1.03	0.58	0.56	0.64	0.63
6	0.25	0.50	0.60	1.11	1.23	0.72	0.64	0.72	0.79
7	0.50	1.00	0.76	1.27	1.51	0.86	0.84	0.88	0.87
8	0.75	1.50	0.92	1.43	1.63	1.00	1.04	1.00	1.03
9	1.00	2.00	1.00	1.55	1.87	1.16	1.16	1.04	1.31
10	1.25	2.50	1.08	1.86	1.99	1.23	1.36	1.28	1.43
11	1.60	3.25	1.32	1.98	2.19	1.28	1.44	1.52	1.55
12	1.95	4.00	1.40	2.14	2.54	1.46	1.68	1.60	1.67
13	2.30	4.75	1.56	2.34	2.74	1.74	1.92	1.72	1.98
14	2.65	5.50	1.91	2.42	2.90	1.85	2.20	1.84	2.14
15	2.90	6.00	2.03	2.46	2.98	2.04	2.32	1.84	2.22
16	3.15	6.50	2.11	2.46	2.98	2.10	2.36	1.84	2.34
17	3.21	6.62	2.11	2.50	2.98	2.12	2.36		2.34
18	3.27	6.74	2.11	2.50		2.12	2.36		2.34
19	3.33	6.86		2.50		2.12			
20	3.39	6.98							
21	3.45	7.10							
22	3.51	7.22							
23	3.55	7.26							
24	3.59	7.30							



AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
DISTRICT WIDE - WEST

CUMETIME	LITQPF	HVYQPF	5MC#3	5MC#36	5MC#1100	5MC#1200	5MC#1300	5MC#1400
0	0	0	0	0	0	0	0	0
1	0	0	0.08	0.04	0.08	0.08	0.04	0.04
2	0.10	0.20	0.16	0.08	0.20	0.16	0.08	0.08
3	0.20	0.40	0.28	0.20	0.32	0.28	0.32	0.12
4	0.30	0.60	0.44	0.63	0.48	0.44	0.48	0.47
5	0.40	0.80	0.79	1.18	0.60	0.60	0.79	0.67
6	0.50	1.00	1.03	1.53	0.68	0.72	0.91	0.83
7	0.75	1.50	1.19	1.61	0.68	0.80	1.03	0.99
8	1.00	2.00	1.39	1.73	0.92	0.84	1.27	1.27
9	1.25	2.50	1.55	1.85	1.12	0.84	1.39	1.43
10	1.50	3.00	1.63	2.01	1.20	0.96	1.51	1.63
11	1.85	3.75	1.67	2.05	1.24	1.04	1.71	1.71
12	2.20	4.50	1.75	2.13	1.36	1.12	1.83	1.83
13	2.55	5.25	1.83	2.17	1.44	1.16	1.91	1.91
14	2.90	6.00	1.87	2.25	1.52	1.36	2.11	2.07
15	3.00	6.40	1.95	2.29	1.60	1.44	2.35	2.27
16	3.10	6.80	1.95	2.37	1.60	1.56	2.47	2.39
17	3.35	6.86	1.95	2.41	1.64	1.60	2.55	2.43
18	3.60	6.92		2.41	1.64	1.60	2.59	2.43
19	3.85	6.98		2.41	1.64	1.60	2.59	2.43
20	4.10	7.04					2.59	
21	4.35	7.10						
22	4.60	7.16						
23	4.64	7.20						
24	4.68	7.24						



AUGUST 24, 1992 HURRICANE LESTER
QPF VERSUS OBSERVED RAINFALL
LENA GULCH

CUMETIME	LITQPF	HVYQPF	5MC#81	5MC#82	5MC#83	5MC#84	5MC#85	5MC#86
0	0	0	0	0	0	0	0	0
1	0	0	0.04	0.04	0.16	0.08	0.04	0.04
2	0.10	0.20	0.12	0.12	0.32	0.20	0.04	0.04
3	0.20	0.40	0.28	0.24	0.67	0.28	0.20	0.16
4	0.30	0.60	0.63	0.63	0.87	0.59	0.32	0.28
5	0.40	0.80	0.83	0.79	1.03	0.83	0.60	0.48
6	0.50	1.00	0.95	0.99	1.31	0.99	0.80	0.68
7	0.75	1.50	1.19	1.19	1.55	1.19	0.96	0.84
8	1.00	2.00	1.43	1.43	1.71	1.47	1.16	1.08
9	1.25	2.50	1.63	1.63	1.87	1.67	1.44	1.32
10	1.50	3.00	1.75	1.79	1.95	1.87	1.60	1.52
11	1.85	3.75	1.87	1.91	2.03	1.99	1.80	1.64
12	2.20	4.50	1.95	1.99	2.19	2.11	1.88	1.72
13	2.55	5.25	2.03	2.11	2.39	2.19	2.04	1.80
14	2.90	6.00	2.19	2.31	2.51	2.39	2.16	1.88
15	3.00	6.40	2.35	2.47	2.59	2.51	2.32	2.12
16	3.10	6.80	2.43	2.55	2.67	2.59	2.40	2.16
17	3.35	6.86	2.47	2.59	2.71	2.63	2.48	2.28
18	3.60	6.92	2.47	2.59	2.71	2.63	2.56	2.28
19	3.85	6.98	2.47	2.59	2.71	2.63	2.56	2.36
20	4.10	7.04					2.56	2.36
21	4.35	7.10						
22	4.60	7.16						
23	4.64	7.20						
24	4.68	7.24