

HENZ METEOROLOGICAL SERVICES
(HMS)

URBAN DRAINAGE & FLOOD CONTROL DISTRICT
FLASH FLOOD PREDICTION PROGRAM
-1990 Operational Season-

HMS FINAL REPORT 90-1
Agreement No. 90-01.11

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INTRODUCTION

Urban Drainage & Flood Control District (UDFCD) has funded a Flash Flood Prediction Program (F2P2) since May 1979. Value-added forecast services of thunderstorm occurrence, rainfall, and flooding have been provided to the F2P2 by a private meteorological service (PMS). These forecasts have been issued directly to pre-arranged contact points in each of the District's six counties and several large cities. The PMS forecasts are site and basin specific and supplement the normal National Weather Service (NWS) issuance of urban flooding statements and flash flood watches and warnings.

Henz Meteorological Services (HMS) was selected in a competitive bid to perform the 1990 F2P2 PMS service. HMS is located in Denver, Colorado and all F2P2 forecasts were made by John Henz and Frank Robitaille. The normal season ran from 15 April to 15 September 1990 but was extended to 30 September due to persistent flooding threats from a lingering monsoonal weather pattern. The season was 169 days long with operational days extending from 0700-2200L. The program covered 2535 hours of weather center operation which was extended to 2705 hours due to nocturnal thunderstorm occurrence. The forecast area supported by the F2P2 is shown in Figure 1.

This report will cover the degree of success achieved by the 1990 F2P2, identify significant weather events, and outline supplemental services provided.

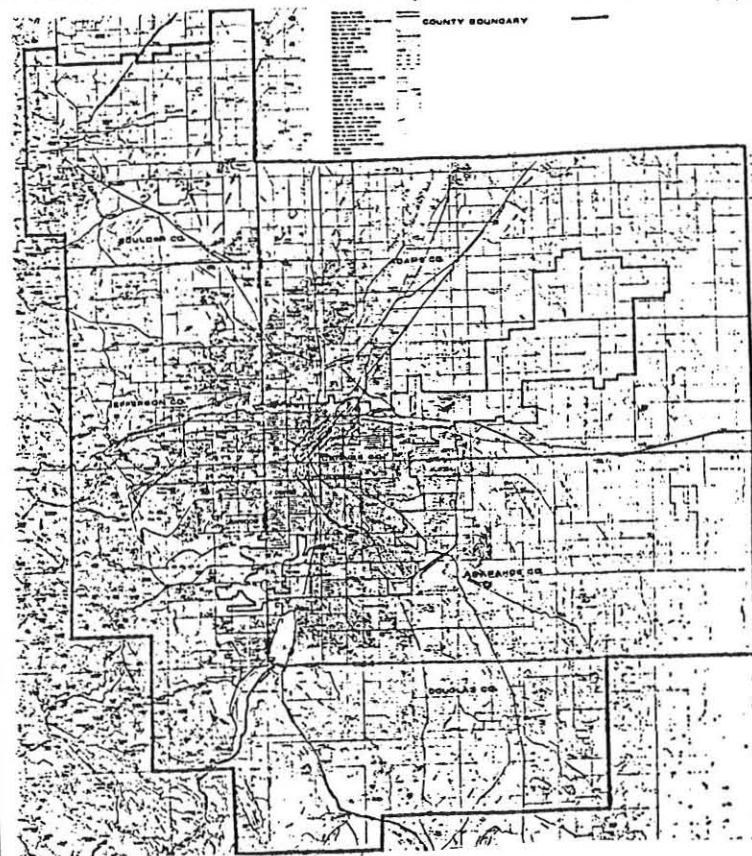


Figure 1 General map of District F2P2 Forecast Area

2.0 DEGREE OF SUCCESS

The 1990 F2P2 is regarded as a very successful program which achieved above average performance. Program success will be presented on a seasonal, District-wide and county/city basin for issuance of Message 1's (M1) and Thunderstorm Advisories (TA). Verification statistics will be provided to support the conclusions.

It will be noted that direct comparisons between the 1990 season and prior years were not possible due to a change in the definition of a Message Day. The 1990 F2P2 Message 1 definition specified that a Message 1 would be issued only when the rainfall prediction called for 1 inch of rain or more to fall within a one-hour period or when the predicted intensity exceeded a 5-year frequency (i.e., 0.5 inches within 10-15 minutes). Considerable judgment was required by the meteorologist of when to and when not to issue a Message 1. Message 1 issuance in prior years was not restricted or defined by quantitative definitions but by a qualitative set of flooding definitions. A more detailed account of the Message 1 differences can be found in District's Flood Hazard News, December 1990.

Seasonal/District-wide

The 1990 F2P2 season defies a description as normal despite its statistical results. The program began with rain and snow on Easter Sunday, April 15th and concluded in sunshine on September 30th. Most F2P2 seasons experience an average of 1 M1 day in April, 2 M1 days in May, and 10 M1 days in June or 13 M1 days by 30 June. In 1990 only 1 M1 day on May 29th had occurred by 30 June. This dry start to the season was unprecedented in the 12 years history of the program. Thunderstorm advisories (TA) were issued on 3 days in April, 15 in May, and 19 in June or 37 days total. These thunderstorms were occurring in the District on almost half of the 77 days but heavy precipitation opportunities were scarce. It should be noted that an isolated heavy thunderstorm occurred on April 24th and dropped hail and 1.24 inches of rain on one ALERT site in Arvada. No Message 1 was issued for this storm though TA's calling for up to 1 inch of rain were issued. Only minor nuisance street flooding was noted.

The dry start to the 1990 season did afford meteorologist Frank Robitaille to "ease" into his first operational F2P2 season as a forecaster. Frank joined HMS after 15 months at AIR, Inc in Boulder which followed 14 years of operational severe weather forecasting and research at the Alberta Research Council in Canada. Prior to working in Canada, Frank participated in 8 years of field research programs in Colorado and abroad. Frank's expertise and professional demeanor contributed strongly to the closing half of the 1990 season.

The dreath of storms prior to 30 June was followed by 12 M1 days in July, 10 M1 days in August, and 7 M1 days in September giving a seasonal total of 30 M1 days in the 1990 F2P2 season. The "second season" was ignited by a furious seven day assault beginning July 4th with a pre-fireworks barrage of heavy rain in southern Boulder and Adams counties and culminating with the 600 million dollar July 11th "hailstorm from hell." More detail on this period will be presented in the section on Significant Event Days. The season extended through September 30th as monsoonal moisture persisted and brought 7 M1 days to September, or three times the average.

A seasonal comparison of the F2P2's since 1979 is presented in Table 1. The 1990 F2P2 was slightly above average in accuracy and below average in false alarm rate compared to prior seasons while the number of observed M1 days of 26 was average. Prior to 1990 a M1 day hit required that at least one District county reported a flooding event while in 1990 it required that a 1 inch/hour or 5-year frequency rain was observed in a District county. The close resemblance of seasons suggests the new M1 day definition was a step in the right direction.

The only disparaging notes were the two M1 events which occurred in Arvada without prior M1 issuance. The first event occurred on April 24th when 1.22 inches of rain fell at Van Bibber Park from 1:30 PM to 2:40PM producing minor street flooding.

TABLE 1

VERIFICATION OF SEASON-BY-SEASON ECR DAY FORECASTS (1979-1985)
FOR DENVER, COLORADO FLASH FLOOD PREDICTION PROGRAM

Forecasts of M1 Days			Percent		
Year	Hit	Misses	M1 Accuracy	False Alarm Rate	Probability of Detection
1979	17	9	65	35	85
1980	23	12	66	34	100
1981	31	9	77	23	100
1982	34	8	81	19	100
1983	32	5	86	14	100
1984	32	6	84	16	100
1985	25	3	89	11	100
1986	30	5	86	14	97
1987	40	7	85	15	100
1988	24	4	86	14	100
E 1989	26	5	84	16	100
1990	26	4	87	13	93
Averages:	26	6	81	19	99

E=Estimated statistics generated for the 1989 season.

While no other gage reported even 0.75 inches, this gage was definitely hit by an intense point rainfall. The second occurrence was also in Arvada on the night of July 19th. This storm moved out of Boulder County where a M1 had been issued into Arvada between 10:00 PM and 11:00 PM. While no ALERT gages were hit, unofficial reports of up to 2.00 inches were received from the public in extreme northwest Arvada. Police reported very localized street flooding in about a 1 square mile area. TA's were in place for Arvada and the storm was observed on radar at HMS and by car. This storm will be studied in more detail to determine ways to prevent future occurrences and identify a suspected local topographic influence on storm intensity and location.

It should be noted that all M1's were issued with at least a 30 minute leadtime. The two events of exception were the two Arvada events for which no M1's were issued. TA's issued on these days had a 90-minute leadtime on April 24th and over a three-hour leadtime on July 19th.

Table 2 shows a monthly distribution of M1 and TA days for the District. TA's were issued for a wide range of thunderstorms which F2P2 users had identified as important. TA's covered the gambit from "garden-variety" storms producing 60 mph microbursts and light rain to the July 11th mega-hailstorm. This wide range of intensity lessened the operational utility of TA's. Fueling this fire of uncertainty was the fact that TA's were issued on 66 days or 40% of the days. TA's and M1's were issued on 46% of the days. The fact that TA's were issued 46% of the days dramatically lowered their utility as noted by F2P2 users. All TA day forecasts verified, but communication overload was noted and will be discussed in the next section on county/city success rates.

TABLE 2

1990 F2P2 Monthly TA/M1 Day Occurrences

Month	TA Days	M1 Days
-----	-----	-----
April	3	0
May	15	1
June	19	0
July	17	12
August	17	10
September	7	7
--	--	--
Total	78	30

County/City Success

A better measure of individual user success is the verification of M1 events on a county or city basis. M1's are issued for all counties in the District and five cities served by District warning systems. The counties are Boulder, Jefferson, Adams, Arapahoe, and Douglas Counties. The cities are Denver, Aurora, Arvada, Lakewood, and Wheat Ridge. A concentrated effort was mounted to verify M1's by county and city in 1990 as part of the Product Evaluation Program (PEP).

The last county/city specific M1 verification was performed in the 1987 F2P2 season. In 1987 353 individual M1's were issued on 47 M1 days. Of the 353 M1's, 155 M1's were verified while 198 M1's were not. Many of the misses were attributed to the lack of adequate rain gage networks but the fact remained on 44% of the M1's verified in 1987.

Since 1987 District has added 47 rain gages for use in the 1990 F2P2 and the complaint still exists that more gages are needed to adequately record rainfall. The primary areas of poor data are Adams County, southern Jefferson, Denver County, southwestern Arapahoe County, and all of Douglas County. Until the areas are covered, complaints will continue.

A daily verification of M1's by county and city is recorded in Table 3. All verifications were made on the basis of raingage reports of 1" or more of rain in an hour or a rainfall intensity of equal to or greater than a 5-year frequency (i.e., 0.5" in 10-15 minutes). Many of these verifications were obtained from District ALERT gages or cooperative NWS or F2P2 observers.

Table 3 shows 189 M1's were issued in the 1990 F2P2 with 139 issued to counties and 50 to cities. Of the 189 M1's, 122 M1's verified or 65% with no difference in county or city verification. A direct comparison of the 1987 and 1990 seasons may not be fair due to differences in raingages, M1 definitions, and a more active year in 1987 for storms: Nonetheless, it is very encouraging to note the 20% improvement in verification on a specific user basis from 1987 to 1990.

Perhaps even more encouraging is a more detailed look at the 30 M1 days. On 21 of the 30 M1 days, 70 M1's of the 87 issued verified or 80%. This verification rate is approaching the original verification noted in 1979 for a M1 day verifying anywhere in the District.

The remaining 9 M1 days were more discouraging. Of the 51 M1's issued, only 4 M1's verified or only 8%. These Big Bust days were attended by active thunderstorms and severe weather 90% of the time, but heavy rainfall was not noted. User support was enhanced on these days by the cancellation of about two-thirds of the M1's by 5:00 PM. Thus overtime requirements were not affected by the false alarms and severe weather kept emergency operations busy most of the time.

Table 3

1990 UDFCD Flash Flood Prediction Program Statistics

Date	Message	Needed not issued	Denver	Adams	Boulder	JeffCo
Apr 24		1				
May 29	1		1	1		
June	none					
Jul 4	1		1	1	1	1
Jul 5	1		0	1	1	1
Jul 8	1		1	0	1	1
Jul 9	1		1	1	0	1
Jul 10	1		0	0	0	1
Jul 11	1		1	1	1	
Jul 19	1	1			1	
Jul 20	1		1	0	1	1
Jul 21	0		0	0	0	0
Jul 27	1					
Jul 29	1		1	1	1	1
Jul 30	1		1	0	0	1
Aug 4	1			1		
Aug 5	1		0	0	1	0
Aug 11	1		1	1		1
Aug 12	0		0	0	0	0
Aug 13	0			0	0	0
Aug 15	1		1	1	0	1
Aug 17	1		1	1	1	1
Aug 18	1		1	1		
Aug 20	1		1	1		1
Aug 31	1		1	1		1
Sep 1	1				1	1
Sep 2	1		0	0	1	1
Sep 3	1				1	
Sep 5	1		1	1	1	1
Sep 6	1		0	0	0	1
Sep 18	1		1			1
Sep 28	0		0	0	0	0
Hit/Miss/Total:			16/8/24	14/11/25	13/9/22	18/5/23
% Correct:			67%	56%	59%	78%
% FAR:			33%	44%	41%	22%

Table 3
continued

Date	WHT	Lakewood	Arvada	Arapahoe	Aurora	Douglas

Apr 24						
May 29						
June						
Jul 4				0	0	0
Jul 5				1		1
Jul 8	1	1	1	0	0	1
Jul 9	1	1	1	1	1	0
Jul 10	1	1	1	1	0	1
Jul 11						1
Jul 19			needed			
Jul 20	1	1	1	1	0	1
Jul 21				0		0
Jul 27						1
Jul 29	0	1	0	1	1	1
Jul 30				1		1
Aug 4				1	1	
Aug 5				1	1	0
Aug 11				1	1	1
Aug 12				0		0
Aug 13				0		0
Aug 15				1	1	1
Aug 17	0	0	0	1	1	1
Aug 18				1	1	
Aug 20	1	0	0	1	0	1
Aug 31	0	0	0	1	1	0
Sep 1	1	1	1			
Sep 2				0		0
Sep 3						
Sep 5	0	0	1	1	1	
Sep 6			1			
Sep 18	1	1	0	1	1	1
Sep 28				0		0
H/M/T:	7/4/11	7/4/11	7/5/12	16/7/23	11/5/16	13/9/22
% Correct:	64%	64%	58%	69%	69%	59%
% FAR:	36%	36%	42%	31%	31%	41%

Total: 189/122/311
65% M1's verified on county/city
basis combined

Over two-thirds of the M1's verified in Denver, Jefferson, and Arapahoe Counties and Wheat Ridge, Lakewood, and Aurora. Less than 60% of the M1's verified in Boulder (59%), Douglas (59%), and Adams (56%) Counties. The disparity in the verification may be due to the lack of gages in eastern Boulder County, northern Douglas County, and eastern Adams County. In 1990 only 3 District ALERT gages were in eastern Boulder County, 2 gages in Adams County, and none in Douglas County. Verifications in these areas were largely dependent on cooperative observers.

Given the high level of user support for the F2P2, the false alarm rates inherent in the above statistics must be balanced by the timely level of support delivered. In general, it appears that two out of three hits may be adequate to retain support.

While verification of TA's was not required in this report some statistics will be shared to support the recommendation that TA's be dropped and replaced by twice daily Heavy Precipitation Outlooks (HPO's) issued on fax and bulletin boards. TA's were issued on almost half (46%) of the days due to frequent thunderstorm occurrence. A total of 516 TA's were issued and released on fax, bulletin board, and phone. TA's were issued on a short fuse with 15-30 minute leadtimes and all TA's verified. However, the sheer volume of TA's flooded dispatchers with too much information and in many cases no clear cut procedures on how to use the TA's information. Meetings with the users at the end of the 1990 season supported the demise of the TA and further fine-tuning of the M1's. A twice daily issuance of HPO's on fax and bulletin board appeared to have effectively replaced the TA for the last 4 weeks of the program. For now the TA is history.

Significant Storm Events

The 1990 F2P2 storm season produced a number of memorable storm dates and an interesting "storm-free" period. This section will briefly identify the primary storm event dates, a primary storm track for the date, and a short commentary on the storm. HMS will publish a more complete data summary on the storms and associated operations prior to the start of the 1991 F2P2 season.

The 1990 F2P2 season began with an unprecedented "storm-free" period from 15 April to 30 June. Few severe thunderstorms and even fewer heavy rain events were noted in this period. Normally the month of June produces the heaviest thunderstorm rainfalls of the F2P2. Only 2 days of this 77 day period produced M1 level rainfalls: April 24 and May 29. Both dates made the list of significant 1990 F2P2 storm events.

A summary of significant 1990 storms is shown in Table 4. Thirteen of the 26 active storm days were selected due to either their unusual occurrence characteristics or intense rainfall. Selection to this list was the subjective choice of the HMS Project Manager.

Table 4
List of Significant 1990 Storm Event Dates
and Brief Storm Summaries

Date	Storm Summary
April 24	An unusually intense, localized t-storm dropped 1.22" of rain at Van Bibber Park, Arvada along with 3-6" of pea-sized hail.
May 29	A severe t-storm formed over west Denver, produced a tornado within 6 blocks of UDFCD, and dropped over 2.55" of rain in portions of north Denver and western Adams County, briefly closing I-25.
July 4	A pre-fireworks storm formed on the Boulder-Jeffco border and dropped 1-2" of rain in less than an hour on parts of southwestern Adams County.
July 8	Heavy t-storm rains dropped 1-1.6" of rain on Lena Gulch and an estimated 1.5-2.5" in an hour in Jefferson and northern Douglas Counties.
July 9	A line of almost stationary storms fired across northern Denver and Jefferson Counties producing one tornado and 1-3" rainfalls which flooded I-70.
July 11	District is clobbered by a long-track supercell t-storm which produced \$450-600 million damage on a track from Lyons (BOCO) to Denver to Castle Rock (DougCo).
July 19	An extremely localized but intense t-storm tracked from the southern Boulder foothills into northwest Arvada and dropped a "measured" 1-3"/hr. rainfall in Boulder County and an estimated 2" point rainfall in Arvada.
July 20	Intense t-storm moved from south Boulder County into western Arapahoe County producing 1-2"/hr. rains and flooding in Englewood, Littleton and Lakewood streets.
August 11	Several groups of severe storms crossed the District and brought 1-2" rainfall and 2" diameter hail to Aurora.
August 15	Evergreen is deluged with 5" pea-size hail and 1.5" rain as Goldsmith, Westerly, and Toll Gate Creeks report minor flooding.
August 17	Intense rush hour storms battered Longmont with 2.35"/45 min. and Arvada with 1-2"/hr. rain causing a housing development roof to collapse.
September 2	Heavy storms dampen Labor Day in the Boulder and JeffCo foothills and close I-70 near Idaho Springs with mud-slides.

Storm tracks for the primary thunderstorm, thunderstorm complex, or storm-lines are presented for the event days in Figures 2-4. The tracks were made after review of video tape records made off of the NWS radar at Limon, Colorado. Of particular interest may be the unusually long track of the severe hailstorm complex of July 11, 1990 which extended from Lyons, Colorado south-southeastward to Castle Rock before leaving the District. This storm eventually dissipated in southern El Paso County south of Colorado Springs. In general, the core of the storm shrunk to 5-10 square miles. The storm moved in a relatively straight line to the south-southeast throughout its life.

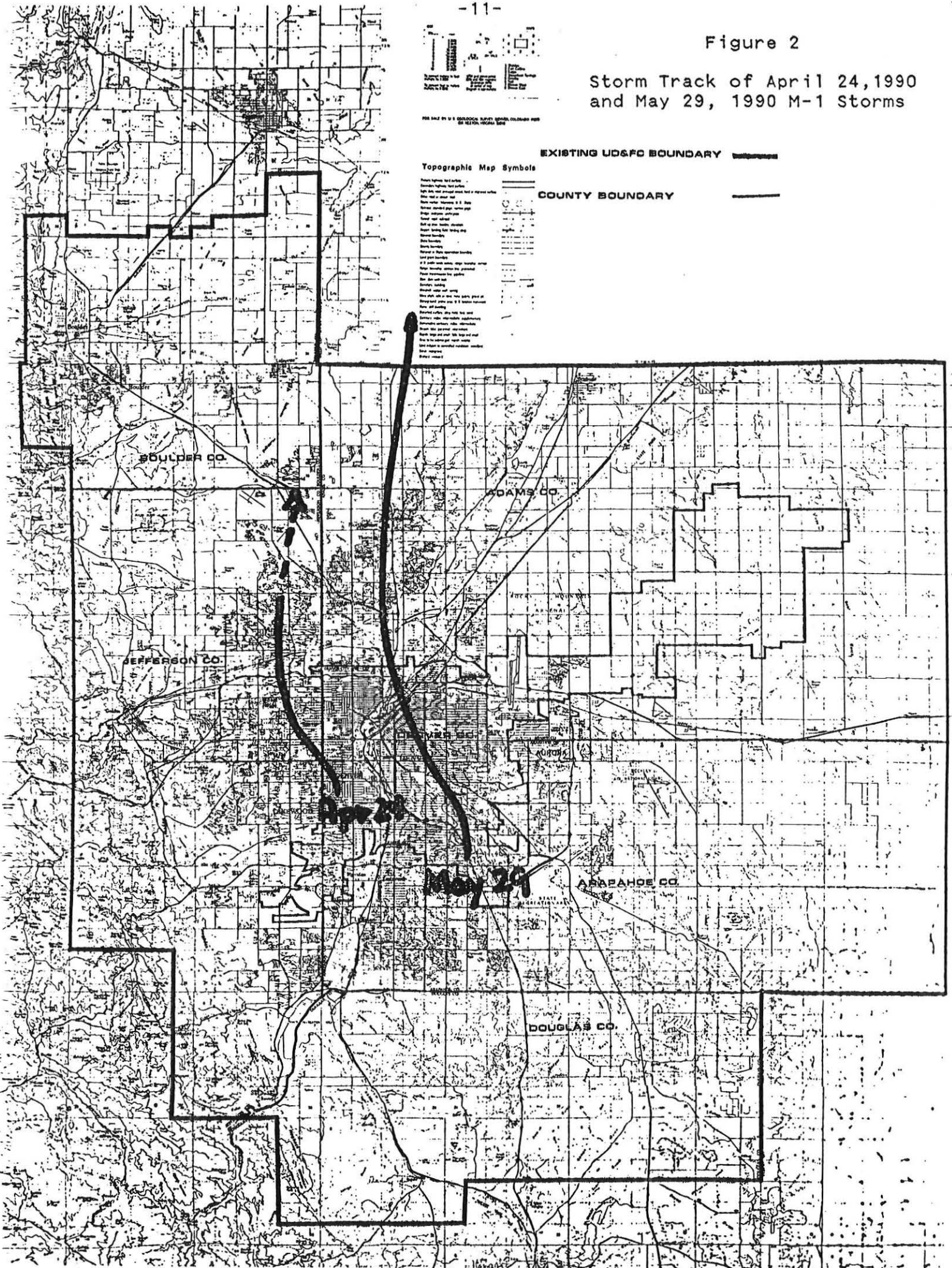
The F2P2 alerted users to the threat of severe thunderstorms by mid-morning of the 11th. TA's calling for severe thunderstorms with 1-2" diameter hail, 60 mph winds, 0.50-0.75" rain/30 minutes, and active cloud-to-ground lightning were issued to all counties between 12:15 and 12:30 PM. Additionally, Boulder County was upgraded to a M1 calling for 1-1.5" rain/30-60 minutes and large hail at 1:15 PM. Denver County and Adams County were upgraded to M1's at 1:50 PM and 1:53 PM respectively. Numerous phone, fax, and computer bulletin board products were issued between 12:15 PM and 4:00 PM as the storm crossed the District.

The path and timing of the storm's movement can best be appreciated by reviewing Table 5 which is a chronology of severe weather events reported to the Denver NWS. Boulder County's main problems in the District were noted from 1:45 PM to 2:00 PM. Northeastern Jefferson and southwestern Adams Counties were impacted from 2:00 PM. Denver was barraged from shortly before 2:30 PM to 2:45 PM while Arapahoe and Douglas Counties were pounded from 2:45 PM to 3:15 PM. The duration at a point location was between 15-20 minutes.

A specific F2P2 user conference was held to discuss the impacts and support provided prior to and during the July 11, 1990 hailstorm. The results of the meeting resulted in a further definition of M1's with "Red Flags" attached and the elimination of TA's for 1991. This concept is covered in detail in the December 1990 issue of the District's Flood Hazard News. Table 6 reviews user leadtime to the occurrence of severe weather reports listed in Table 5. Leadtime was time elapsed in minutes from issue time to severe report time. In general, the District and F2P2 users were alerted to the likelihood of severe thunderstorm activity from 9:00 AM ECO through the individual Severe Thunderstorm TA's issued to users. Many agencies were able to use the leadtime to protect property and pro-actively prepare for the storm.

A more complete verification of message days, TA's, QPF's, and storm tracks will be included in the HMS 1990 F2P2 Operation Report which will be released in Spring 1991. In general, the 1990 season afforded an excellent opportunity to test new products and dissemination techniques.

Storm Track of April 24, 1990
and May 29, 1990 M-1 Storms



Storm Track of Significant
July 1990 F2P2 Storms

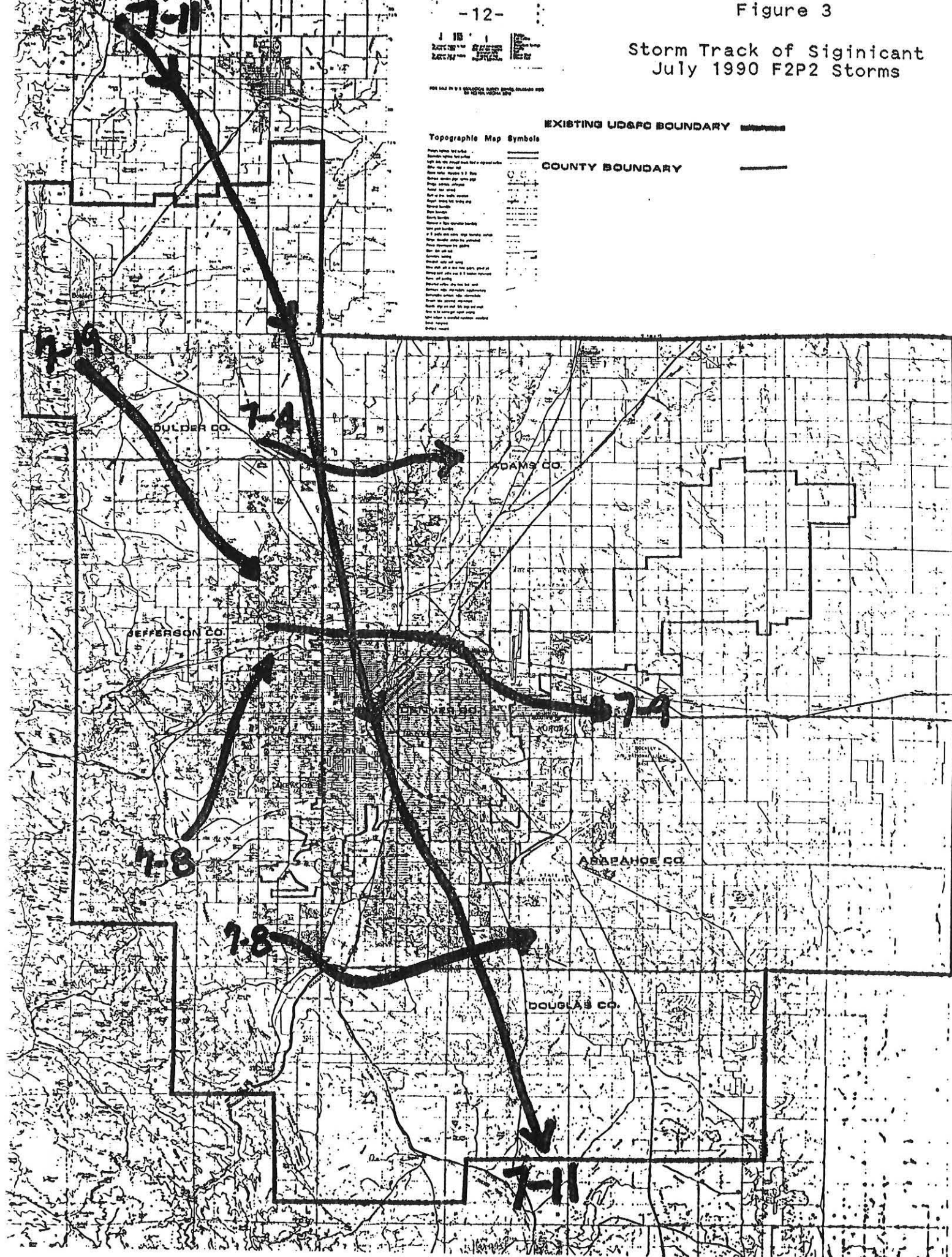


Figure 4

Storm Track of Significant
August and September 1990
F2P2 Storms



FOR SALE BY U.S. GOVERNMENT, BUREAU OF LAND MANAGEMENT, DENVER, COLORADO 80202

Topographic Map Symbols

- Mountain peaks and ridges
- Contours
- Water bodies
- Settlements
- Transportation
- Vegetation
- Other features

EXISTING UDAPC BOUNDARY

COUNTY BOUNDARY

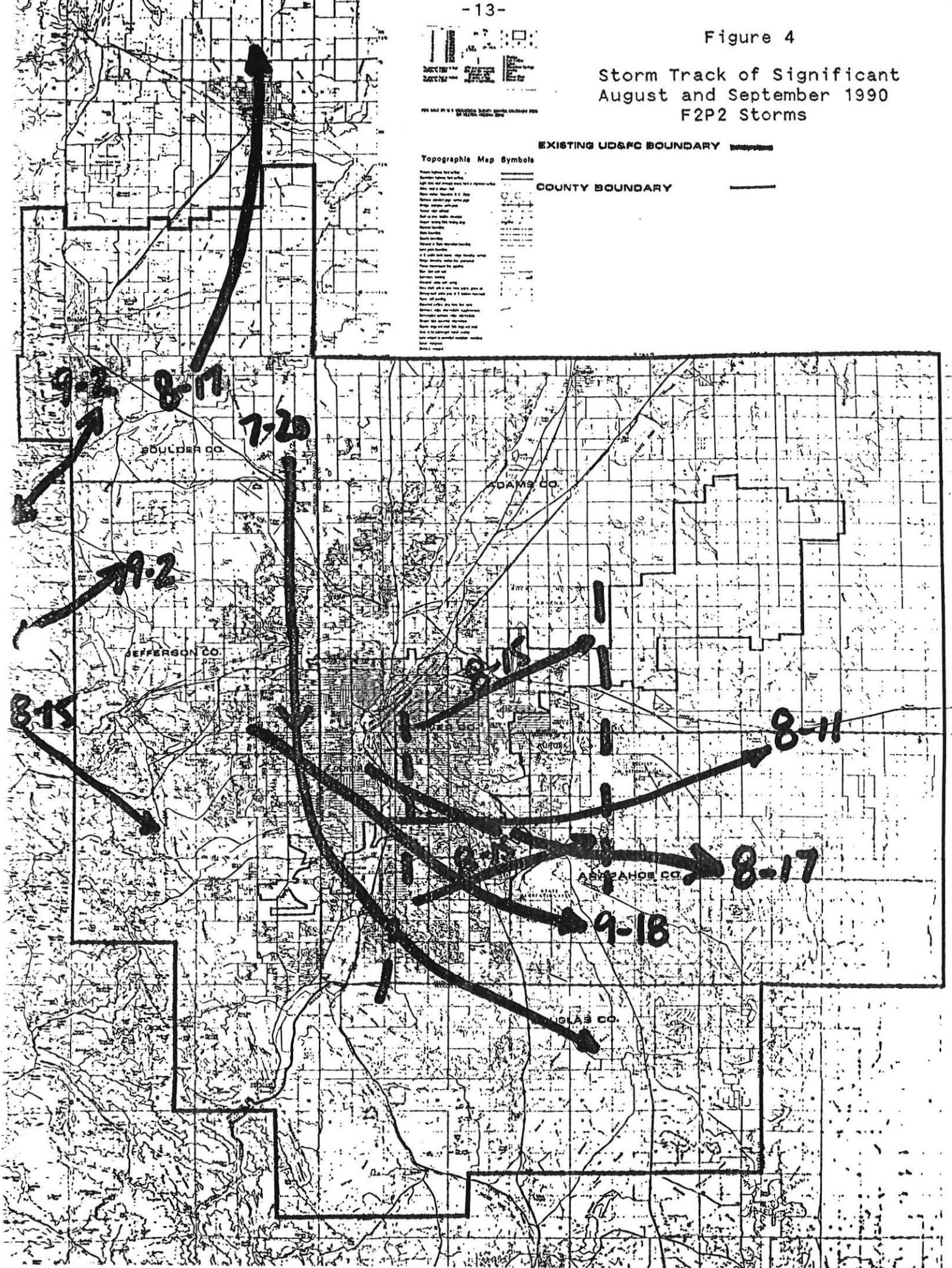


Table 5

Cronology of Official Severe Weather Reports,
National Weather Service-Denver on July 11, 1990

DENLSRDEN
TTAAOO KDEN 120424

STORM REPORT...UPDATED
NATIONAL WEATHER SERVICE DENVER CO
1020PM MDT WED JUL 11 1990

STORM REPORT FOR WEDNESDAY JUL 11 1990...

TIME (MDT)	COUNTY/LOCATION	EVENT
145 PM	BOULDER/PROFS	1 " HAIL
148 PM	BOULDER/BOULDER	3/4 " HAIL
151 PM	BOULDER/BOULDER	1 " HAIL
205 PM	BOULDER/LOUISVILLE	1 " HAIL
205 PM	JEFFERSON/BJC	1 " HAIL
207 PM	JEFFERSON/WESTMINSTER	1 " HAIL...TREES STRIPPED.
210 PM	JEFFERSON/ARVADA	1 " HAIL
211 PM	JEFFERSON/ARVADA	1 " HAIL
217 PM	ADAMS/THORTON	3/4 " HAIL
218 PM	ADAMS & JEFFERSON/WESTMINISTER	3/4 " HAIL
220 PM	JEFFERSON/USFS	1 1/2 " HAIL WND G50
220 PM	JEFFERSON/ARVADA	1 " HAIL
222 PM	JEFFERSON/53RD WADSWORTH	BASEBALL SIZE HAIL
224 PM	JEFFERSON/ARVADA	2 " HAIL
225 PM	JEFFERSON/ARVADA	2 " HAIL
227 PM	JEFFERSON/ARVADA	GOLFBALL SIZE HAIL
231 PM	JEFFERSON/WHEATRIDGE	GOLFBALL SIZE HAIL
232 PM	DENVER/NW DEN	1 " HAIL
232 PM	DENVER/FEDERAL HEIGHTS	1 1/2 " HAIL
240 PM	DENVER/6TH & KIPLING	PUBLIC CONFIRMED TORNADO
241 PM	DENVER/EMERSON AND I-25	GOLF BALL HAIL
244 PM	DENVER/I-25 AND HAMPDEN	GOLF BALL HAIL
246 PM	DENVER TECH CENTER	3/4 INCH HAIL
254 PM	ARAPAHOE/ENGLEWOOD	SOFT BALL SIZE HAIL
256 PM	ARAPAHOE/LITTLETON 2E	1 " HAIL
316 PM	DOUGLAS/CASTLE ROCK 2E	2 " HAIL
313 PM	DOUGLAS/N OF CASTLE ROCK	CAR WINDOWS OUT
315 PM	DOUGLAS/FOUNDERS VILLAGE 2E OF CASTLE ROCK	TORNADO REPORTED BY CASTLE ROCK POLICE CAUSED HEAVY DAMAGE TO HOMES AND VEHICLES. (THIS REPORT RECEIVED AT 5PM).
TIME ?	DENVER/6TH & OSAGE	LARGE TREES DOWNED
TIME ?	DENVER/ELITCH GARDENS	REPORT OF NUMEROUS INJURIES PROBABLY FROM LARGE HAIL AND PROBABLY ABOUT 230PM.

NOTE: ALL OF THE ABOVE REPORTS WERE FROM A SINGLE SUPERCELL
THUNDERSTORM. NUMEROUS REPORTS OF MINOR DAMAGE (NOT LISTED) WERE
RECEIVED. IT IS LIKELY THAT THE FINAL DOLLAR VALUE WILL BE SIGNIFICANT.

RTG/HOLZINGER

Table 6

Leadtime of Severe Weather Advisories and M1's Issued
on July 11, 1990 to F2P2 Users

* Product -----	Agency -----	Issue Time -----	Leadtime to Severe Reports, Table 4 -----
1. ECO-Severe Weather	All (Fax/EBB)	900 AM	4-6 hours
2. HPO-Severe Weather	All (Fax/EBB)	1200 PM	1-3 hours
3. Severe Weather TA's	Boulder	1211 PM	60-90 minutes
	Jefferson	1217 PM	130 minutes
	Arvada	1219 PM	111 minutes
	Wheat Ridge	1222 PM	129 minutes
	Lakewood	1224 PM	130 minutes+
	Adams	1226 PM	111 minutes
	Denver	1227 PM	125 minutes
	Aurora	1232 PM	no severe reports
	Arapahoe	130 PM	74 minutes
	Douglas	135 PM	81 minutes
4. M1 Upgrades	Boulder	115 PM	30 minutes
	Adams	150 PM	27 minutes
	Denver	150 PM	42 minutes

* Severe Weather in the form of 1-2" diameter hail, high winds of 60 mph+, and wind-driven rainfall were indicated in all products on July 11, 1990. Numerous additional phone call, fax, and EBB products were issued on July 11, 1990.

3.0 SUPPLEMENTAL PROGRAMS

In addition to the F2P2 base operations, three new programs were instituted for 1990:

- a. Storm/Archive/Video Evaluation (SAVE)
- b. QPF Spatial Coverage Fax Map Program
- c. Prediction Evaluation Program

This section of the report provides some information on each new program and identifies key results which contributed to the success of the 1990 F2P2.

Storm/Archive/Video Evaluation Program

The Storm/Archive/Video Evaluation (SAVE) program was run from June 1 to September 15, 1990. The SAVE program's objective was to provide a video tape record (VTR) of thunderstorm activity for all days M1's were issued from June 1 on. A VTR was made for the 25 days listed in Table 7. The VTR was made off of the District's Sony 27" color monitor rendition of the Kavouras C2R2 signal of the NWS radar in Limon, Colorado. The taped record of M1 days has provided valuable input to the following F2P2 activities:

- a. Provided an opportunity to "replay" the previous day's F2P2 activity and answer F2P2 county and city questions on where storms happened.
- b. Provided direct evidence of thunderstorm origin, development sequence, and storm tracks. Invaluable information on the July 11, 1990 hailstorm was obtained.
- c. Assisted in documentation of storm location and intensity over flooded basins for QPF verification.
- d. Assisted in providing spatial coverage information for predicted thunderstorm systems.

The SAVE program provided District with a compatible archive of the source of the rainfall reported in District ALERT gages. The value of this data base should grow as District efforts to understand the spatial and temporal distribution of rainfall increase in years ahead. It is recommended strongly that this program be continued for the 1991 F2P2 season.

QPF Spatial Coverage FAX Map Program

The original intent of the QPF spatial coverage fax map program was to provide QPF users with a predicted graphical portrayal of the areal coverage, storm track, and storm size on M1 days from June 1 to September 15, 1990. Additionally, a new QPF storm mass curve product for 1, 5, 10, 15, and 50 square mile areas was to be jointly disagreed with District for issuance to users.

This program was re-directed in May 1990 to two primary products:

- a. A predicted storm track fax map was to be produced for M1 days with a 30 minute leadtime.
- b. The HMS Canon 850 fax was used to send copies of ECO, HPO, IMS, and QPF products directly to F2P2 users.

Storm track maps were issued for all M1 days from June 1 to 15 September 1990. An example of the storm track forecast for July 11, 1990 is shown in Figure 5. This map was issued at 1:50 PM and delivered by fax to users by 1:53 PM. The storm track proved to be 30 degrees too far to the east of the actual track noted by a broad dashed line. However, the product was quite well received by users.

The Storm Track/Fax program is strongly recommended for the 1991 F2P2 program. Fax transmission of F2P2 products will greatly enhance the ability of users to receive and re-transmit an unaltered hard copy within their county, city, or agency.

Prediction Evaluation Program (PEP)

The Prediction Evaluation Program or PEP was the least visible but possibly most productive of the three programs. PEP activities included evaluations of the timeliness or leadtime of M1's, accuracy of QPF products, and correlation of storm tracks to actual weather. It should be noted that valuable insights were gained in each of these areas within 48 hours of M1 days which were immediately used to fine-tune the program.

The leadtime analysis of the July 11, 1990 F2P2 products was very effectively available for the F2P2 users' meeting conducted by District on July 18, 1990. All M1's had at least a 27 minute time and averaged well over one hour for the season.

Verification of QPF forecasts were done for all M1 days as shown in Figures 6-9. Each figure shows the HMS predicted storm mass curves plotted against rainfall observed in District ALERT gage networks. In each case of QPF verification, copies of the HMS QPF versus observed rainfall was presented to District within 48 hours of the event to promote timely evaluation and verification for use with local government agencies. Additionally, the QPF verification plots allowed HMS meteorologists the opportunity to adjust prediction schemes and appreciate the differences between the observed and predicted rainfall.

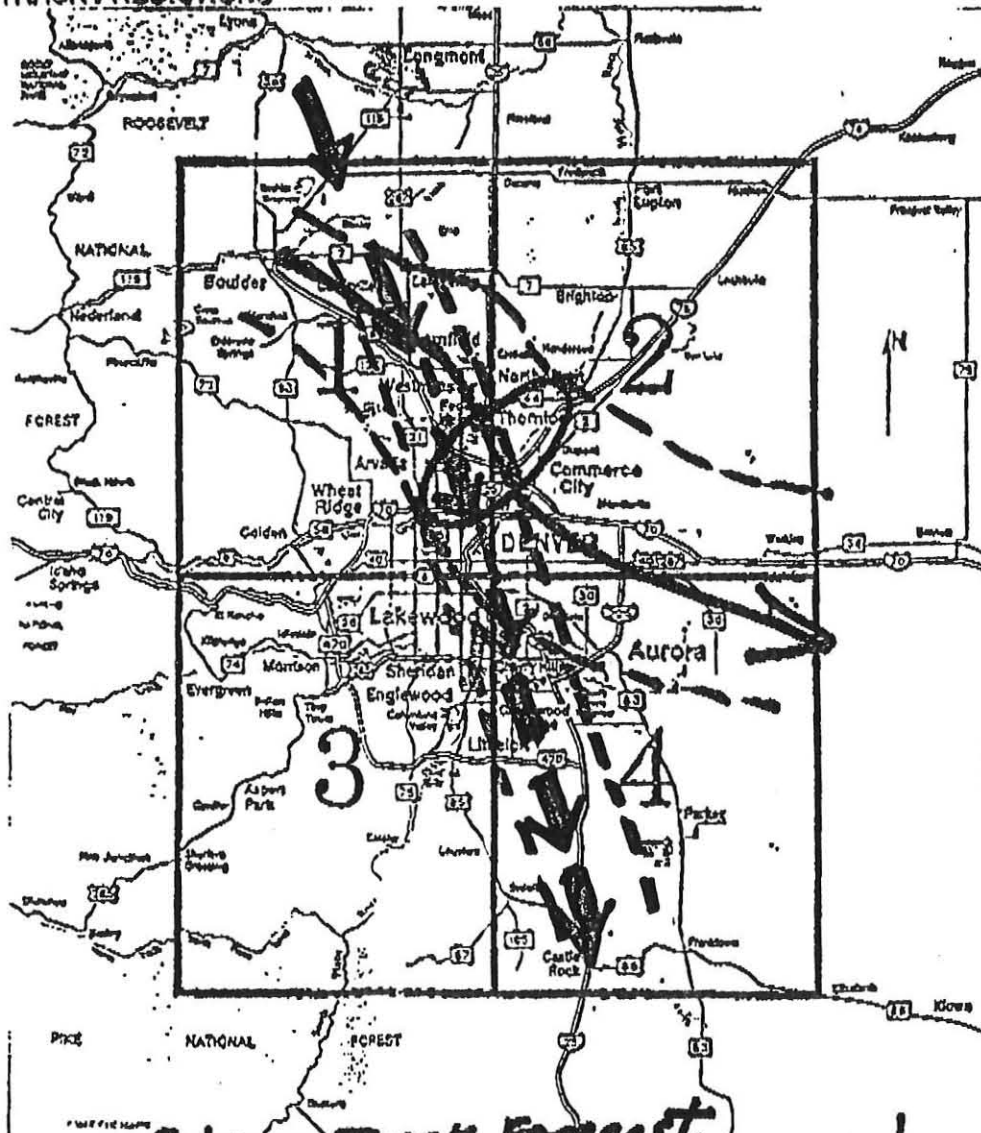
Figure 5

Example of QPF FAX Storm Track For July 11, 1990
Hailstorm Issued at 150 PM

UDFCD FLASH FLOOD PREDICTION PROGRAM (F2P2)

HENZ METEOROLOGICAL SERVICES
QUANTITATIVE PRECIPITATION FORECAST (QPF)
FAX MAP / STORM TRACK PREDICTIONS

7-11-90
130 PM



Storm Track Forecast:
Severe Thunderstorm Batling District!

VALID: 2:30 PM -> 4:00 PM

1. RAIN: 1-1.5" / 30 min = street flooding
2. HAIL 1-2" diameter hail
3. Threat of tornado as storm passes

Henz Moderate risk to life + property

Figure 6

Obs vs HMS QPF Rainfall Lena Gulch Storm July 8, 1990

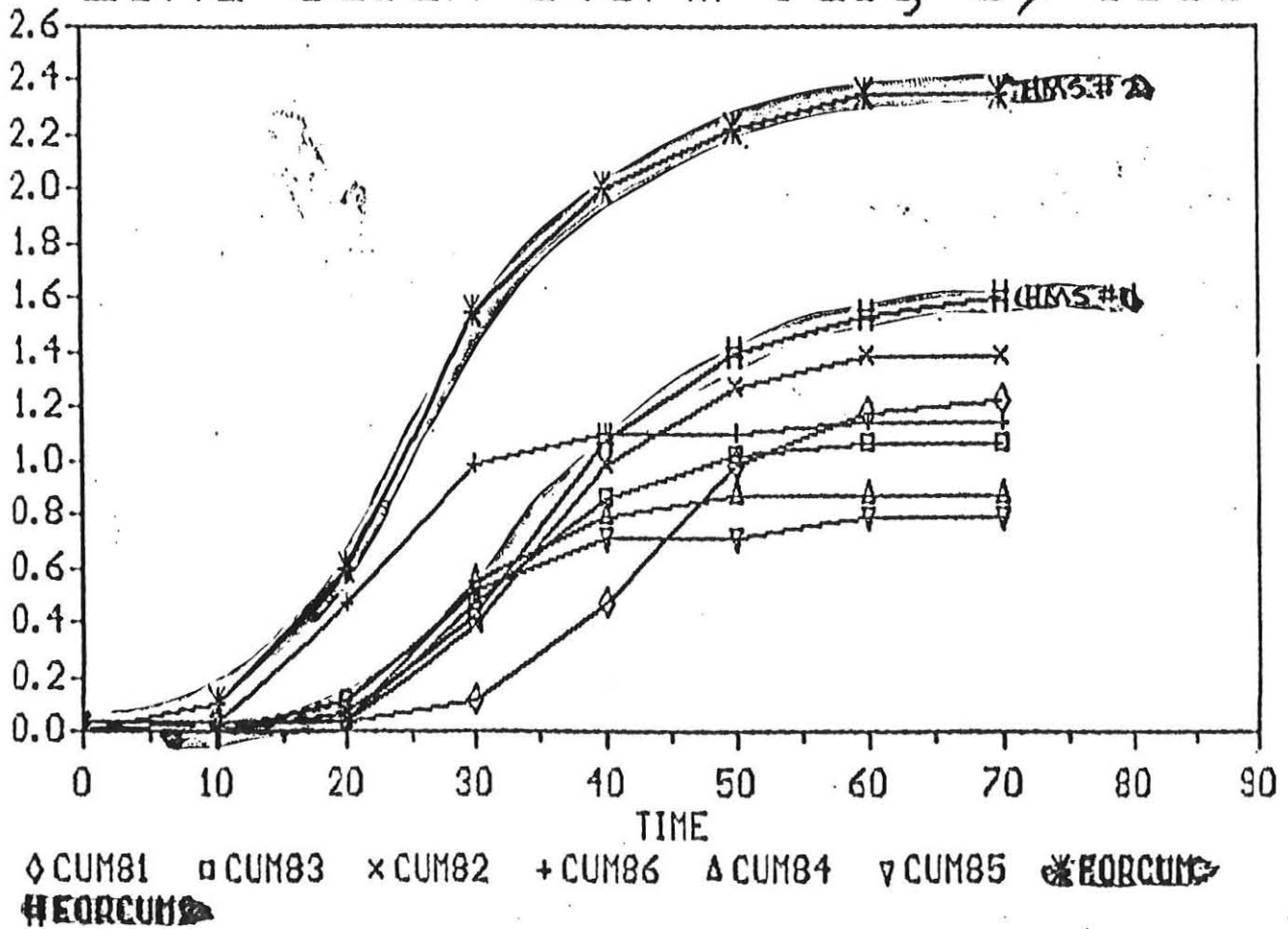


Figure 7

Denver Urban Flood, 7-09-90

Obs vs HMS QPF Cumulative

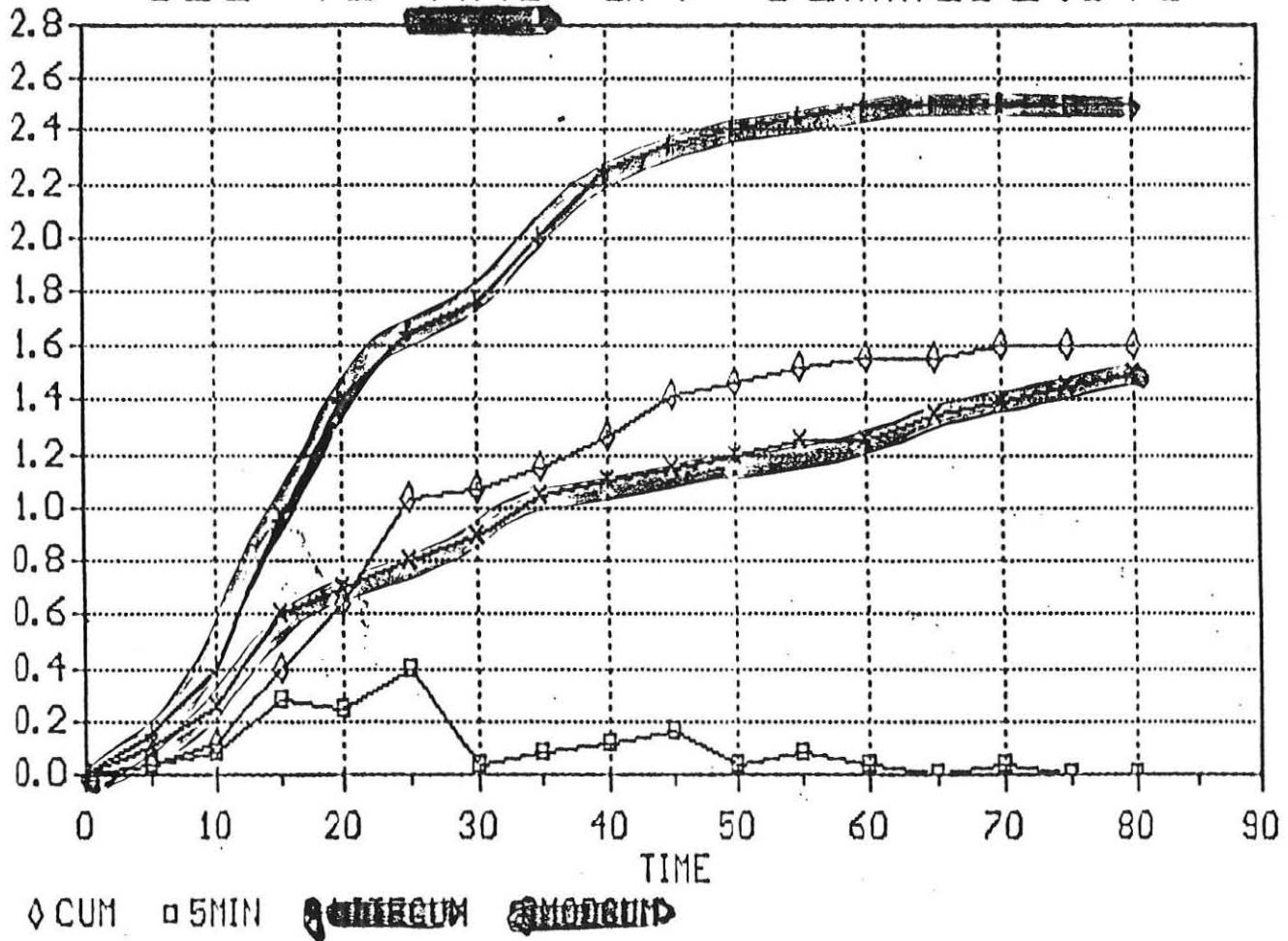


Figure 8

Aurora Urban Flood 8-15-90 Obs vs HMS QPF Cumulative

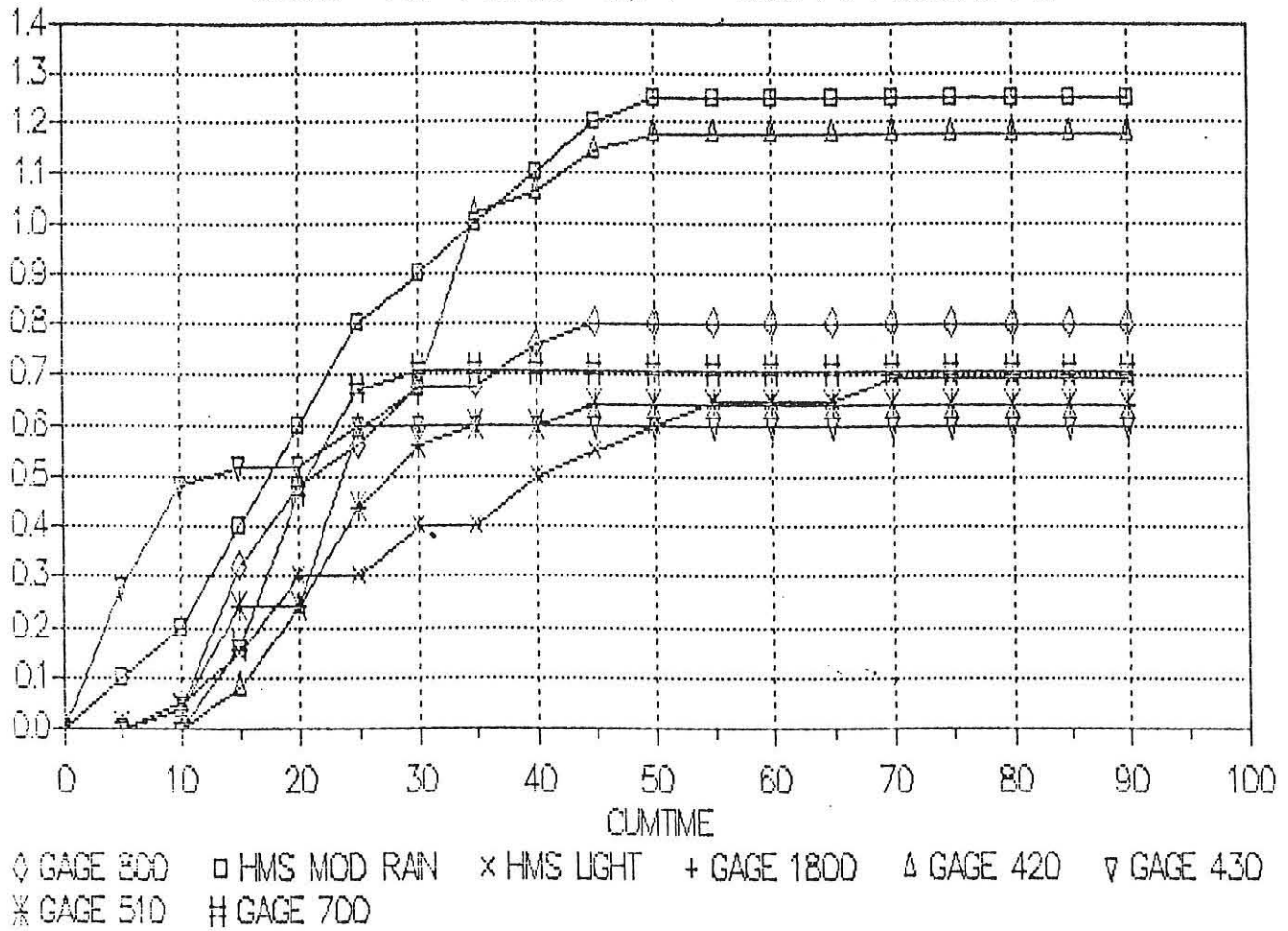
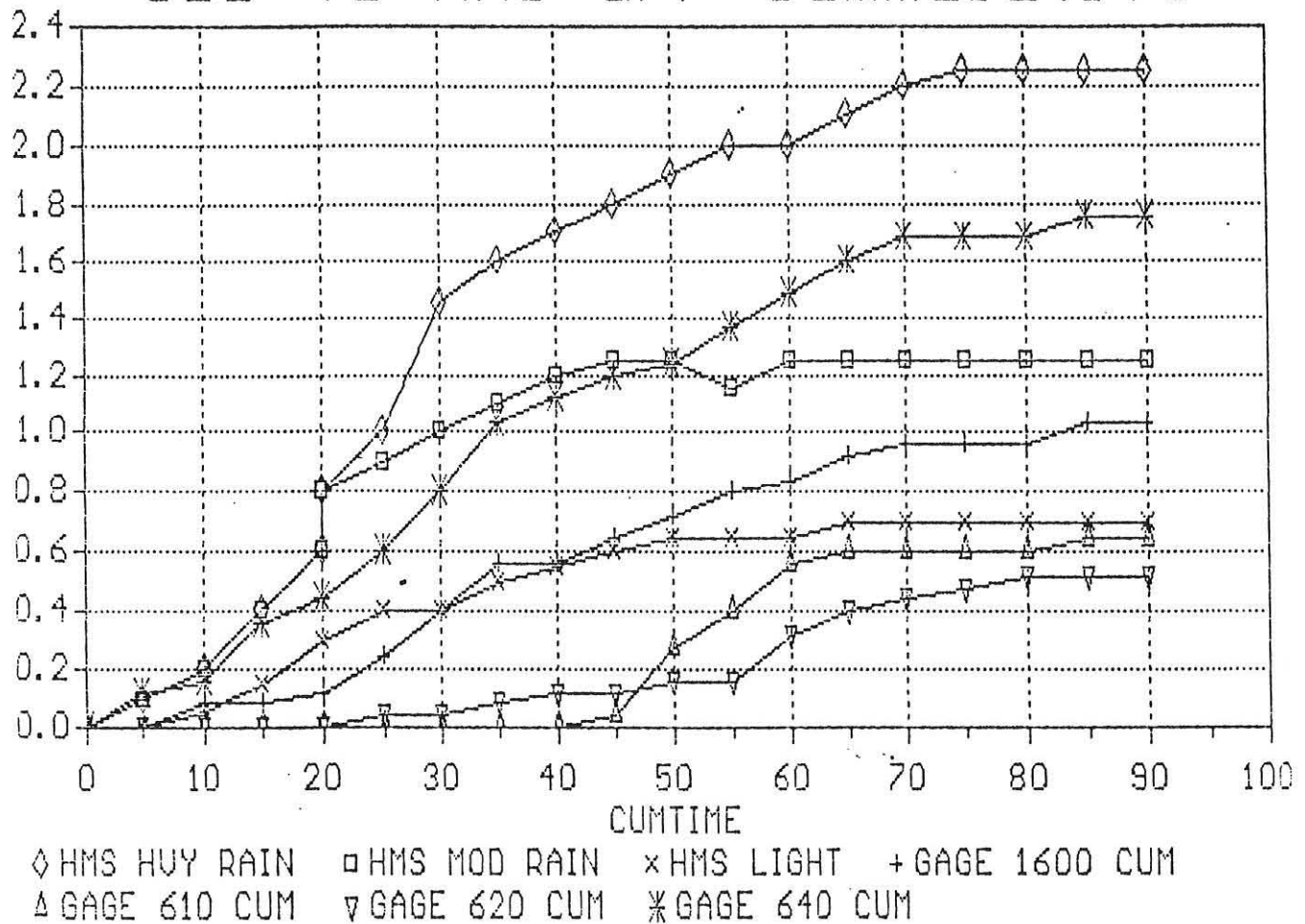


Figure 9

Goldsmith Gulch Flood 8-15-90 Obs vs HMS QPF Cumulative



It should be noted that the QPF cases presented for July 8, 1990, July 9, 1990, and August 15, 1990 storms were typical of QPF performance. The QPF forecasts were created using HMS Convective Storm Model or CSM model output. All initial HMS QPF's are produced before noon daily or before storm clouds begin forming. While the HMS QPF's are not perfect, it is encouraging to note the general ability of the CSM to anticipate the amount and temporal precipitation distributions. A more complete QPF PEP will be found in the HMS 1990 F2P2 Operations Report.

Finally, PEP funding allowed HMS the opportunity to call F2P2 users the morning after a M1 event for the purpose of eliciting immediate user feedback on F2P2 products. These informal surveys were noted in the log and used to fine-tune customer support daily.

4.0 CONCLUSION

The 1990 F2P2 can be judged as a very productive and successful storm season. The introduction of new Message 1 (M1) definitions affected operations very positively as evidenced by improved M1 verification on a District, county, and city basis. The use of facsimile machines to hasten the accurate transmittal of F2P2 products was extremely successful and appears poised to explode during the 1991 F2P2 season.

The introduction of Frank Robitaille into the F2P2 brought a higher degree of professional expertise and polish to the program which was readily evident in improved hail forecasts. Frank's insights were especially keen on July 11, 1990, Denver's Half-Billion Dollar Hailstorm Day.

New fax storm track products were enthusiastically embraced by users while a video tape radar archive program recorded complete radar records of all important storms. A daily Product Evaluation Program enhanced fine-tuning of QPF, storm track, and general F2P2 products by HMS and afforded direct customer input into product evaluation. In conclusion, the prognosis for the 1991 F2P2 appears bright and very encouraging.

Table 7 SAVE Program Video tape storm dates for 1990 F2P2

Month -----	Recording dates -----	Total -----
May	0	0
June	19	1
July	4,5,8,9,10,11,20,22,23,27,28,29	12
August	1,3,4,11,15,17,18,20	8
September	1,2,5,6,18	5
	Total	----- 26

HENZ METEOROLOGICAL SERVICES
MORNING CONVECTIVE OUTLOOK
DATE/TIME: 1045AM WEDNESDAY, JUNE 13 1990

.....WARMING AND DRYING SOUTH WINDS TODAY.....

Mother Nature is approaching Father's Day weekend by taking a few days off from local convective activity while setting the stage for a thundery encore June 15 to 21st. For today the weather question is not to boom or not to boom but how warm and how windy? Yesterday's cold front has penetrated deep into southern plains but is pressed up against the Continental Divide just 30 miles to west. Strong south winds along this frontal zone will howl at 20 to 45mph today and into tonight as the warm air west of the Divide surges northward and eastward to return summery conditions. Today's highs will reach near 80 degrees but could surge into upper 80's if winds shift to southwest. In either case it's too dry to thunder. In the longer term very cold air for June is sinking into the Great Basin. I expect an answering surge of moist, warm sub-tropical air to head out of Mexico into New Mexico, Arizona and Colorado by Father's Day. If the Mexican connection occurs we'll face heavy rain and severe weather June 15-21. HENZ

Figure 14