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1999

"FINAL REPORT"

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 unique with basin-/storm-specific 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 60 percent of Colorado's population in a roughly 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. The population in this area has increased ~20 percent in the period of 1990 to 1999 and prediction service requests have increased noticeably in the past three years in Boulder, Douglas and Arapahoe Counties.

Henz Meteorological Services (HMS) of Denver was selected as the 1999 F2P2 Private Meteorological Service. HMS provided similar services for the 1990 to 1998 F2P2's. HMS forecast services were provided by meteorologists **John Henz and Bryan Rappolt**.

2.0 1999 Operational Season

The F2P2 season began on 15 April 1999 and continued through 15 September 1999 for **154 operational days**. Normal operational hours were from 0700L to 2200L and covered **2,322 hours**. During the period from 1000PM to 0200AM HMS meteorologists added an **additional 104 hours** of support time as storms in eastern Adams, eastern Arapahoe and northern Douglas Counties persisted over newly populated areas near Denver International Airport, Parker and eastern Aurora. Overnight forecasting from midnight to 700 AM added an **additional 142 hours** for a total of **2,568 hours of F2P2 activity**. This 10 per cent increase in operational hours past 2200 is due to population increase in eastern portions of the District in Adams, Arapahoe and Douglas Counties.

The F2P2 required a continuous **Metwatch** of the District for the entire period using the NWS WSR-88D Doppler radar, satellite, conventional surface and upper air observations and local ALERT and mesonet networks. These observations were used by HMS meteorologists to prepare in-house analyses, predictions and specialized F2P2 products. These products included daily **Heavy Precipitation Outlooks (HPO), MESSAGE 1, 2, 3 and 4's, Message updates, Quantitative Precipitation Forecasts (QPF) and Storm Traks**. The HPO's were issued at least once daily to describe the potential for heavy precipitation in each of the District counties. Messages were issued on those days when the potential of heavy rainfall capable of producing some form of flooding in the District or a portion of the District was deemed possible. QPF's and Storm Traks were issued on Message days to provide additional weather support to the F2P2 user community.

No Figure
See 1997 report figure.

3.0 1999 F2P2 Operational Product Production

The F2P2 is designed to offer a unique, basin-specific weather information source concerning heavy precipitation, urban flooding and flash flooding threats to the six participating District Counties and the cities within those counties. Direct basin specific support is rendered to the District basin-specific warning plans identified below:

1. **Boulder Creek Warning Plan**, which serves Boulder/South Boulder Creeks in Boulder County, which impacts the City of Boulder.
2. **Lena Gulch Warning Plan**, which serves the Lena Gulch Basin and impacts Jefferson County, Golden, Lakewood and Wheat Ridge.
3. **Goldsmith/Harvard Gulch Warning Plan** which impacts south central Denver.
4. **Westerly Creek Warning Plan**, which impacts eastern Denver and western Aurora.
5. **Toll Gate Creeks Warning Plan**, which impacts central and southern Aurora.
6. **Ralston Creek Warning Plan**, which impacts central Arvada.
7. **Bear Creek Warning Plan**, which impacts Jefferson County and southern Lakewood.

Five specific F2P2 products exist as expert-to-user support. These products are **Heavy Precipitation Outlooks (HPO)**, **Messages**, **Internal Message Status's (IMS)**, **Quantitative Precipitation Forecasts (QPF)** and **HMS Storm Trak Predictions (FAX Map)**. During the 1998 season HMS delivered the following quantities of the identified F2P2 Fax Products:

Table 1 1999 F2P2 Production Summary

Product	Number issued
Heavy Precipitation Outlook (HPO)	7,442
Message Forms, Updates and Faxes	988
Internal Message Status (IMS)	2,090
Basin-Specific Quantitative Precipitation Forecasts (QPF)	289
StormTraks	3,918
Total	8,028

These products were delivered via fax to participating agencies. The majority of the faxes were sent on either the HMS Communications fax machine, the internal fax card on the HMS F2P2 Communications workstation or on the US West Broadcast Fax service network. Broadcast fax was used to send high impact products with a short "shelf life" such as Storm Traks and IMS's.

While fax service dominated the "hard copy" F2P2 products, significant electronic copy service was provided to the F2P2 via **the District's Electronic Bulletin Board (EBB)**. All HPO, IMS and QPF products were sent to the District EBB for either re-dissemination or dial-in customer support. HMS sent an estimated **291 HPO products, 183 IMS and 17 QPF** products through the District's EBB. The on-demand access of the EBB products to decision-makers using office and home computer systems is a desirable asset of the EBB service. HMS logged over **2,100 storm-related**

telephone interactions during the program, emphasizing the **strong technical "touch"** of the program in the local community. HMS used three dedicated telephone lines: two for voice and one for fax products. These three lines were adequate to handle the volume of communications generated during peak storm periods. User input indicates that the quality of the faxed Storm Traks has improved sufficiently to supplant event verbal "hand-holding" to some degree.

4.0 1999 F2P2 Operational Verification

The **primary service rendered by the F2P2** to participating local governments and associated emergency response agencies **is the issuance of value-added weather forecasts of flash flooding potential, 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 definition of each Message is given below in **Table 2**.

Table 2 Message Definitions used in the District Flash Flood Prediction Program (F2P2)

MESSAGE 1 (*Internal Alert*)

A Message 1 is an advisory message meant to inform key people in local emergency response community that weather conditions are such that flood producing storms could develop later in the day. It is issued after forecast discussions between HMS and National Weather Service (NWS). The advisory is preceded by the statement, " THIS IS A RED FLAG MESSAGE", when HMS deems priority handling by communications dispatchers is required.

MESSAGE 2 (*Flash Flood Watch*)

This Message indicates that a Flash Flood Watch has been issued by the NWS **and/or** HMS feels that the risk is high that a life-threatening flood may occur later in the day. This Message requires priority handling by communications dispatchers.

MESSAGE 3 (*Flash Flood Warning*)

This Message indicates that a Flash Flood Warning has been issued by the NWS **and/or** HMS feels that the risk is high that a life-threatening flood is imminent. This Message requires priority handling by communications dispatchers.

MESSAGE UPDATE

This Message is used by HMS to provide additional information to any of the above Messages on the developing weather situation. For example, this Message has been used to narrow a NWS Watch or Warning area, as more information becomes available or to provide more site-specific information during an event. If HMS feels that this Message requires priority handling by a communications dispatcher, it is preceded by the statement, " THIS IS A RED FLAG MESSAGE ".

MESSAGE 4 (*All Clear*)

This Message cancels the flood potential status. HMS issues it after consultation with NWS and other entities involved with direct HMS communications.

The issuance of F2P2 Messages is quantitatively linked to both the rainfall potential of the weather events and the response of the District basins to the rainfall. **Table 3** shows the criteria for Message issuance based on both the rainfall potential and the anticipated response of the District basin.

Table 3: UDFCD Flash Flood Prediction Program Message Criteria

UDFCD FLASH FLOOD PREDICTION PROGRAM
MESSAGE CRITERIA

Message 1:	Issued primarily to alert local governments to the threat of nuisance flooding of streets and low lying areas due to thunderstorm rainfall when storm total rainfall is 0.50" - 1.00" in one hour or less. When rainfall is 1.00" to < 3.00" in one to three hours, urban street and stream flooding becomes a significant problem. M-1 lead-times of >1 hour are desirable.
Message 1 Rainfall Intensity Criteria:	Any of the forecast rainfall intensities below prompt a Message 1 issuance 1.00"/ 60 minutes 0.75"/ 30 minutes 0.50"/ 10 minutes
Message 1: RED FLAG	Issued to identify storm events, which fall just short of producing life-threatening rainfall, but produce a significant impact on street runoff.
RED FLAG Rainfall intensity:	Rainfall rates are predicted or observed to exceed 1.00"/30 minutes and the storm is considered imminent .
Message 2:	Issued to local governments when the threat of potential life threatening flooding is predicted or the NWS issues a Flash Flood Watch. A HMS-generated M-2 is the equivalent of a Flash Flood Watch. M-2 lead-times of several hours are desirable.
M-2 Rainfall intensity criteria:	>3.00"/hour or a lower value based on mutual discussion between NWS, District and HMS due to antecedent rainfall impacts on soil saturation and/or runoff characteristics.
Message 3:	Issued to local governments whenever a life-threatening flash flood is imminent or the NWS issues a Flash Flood Warning. M-3's are issued in accordance with basin-specific warning plans if available or at the discretion of the meteorologist.

4.1 Message Verification

Evaluations of program performance are based on the correct prediction of the rainfall and event occurrences, which verify the criteria presented in Figure 3. An effort has been made to verify all program forecasts by these criteria. **Table 4** presents a monthly verification of all Messages issued in the 1999 F2P2. Three forms of Message verifications are presented. A **Message 1 (M-1) Day** is any day a Message 1 was issued within the District. A **M-1 Day hit** refers to a day when a M-1 verifying event occurred which equaled or exceeded the rainfall criteria in **Table 3** within the County or City for which the Message was issued. Message 1's are issued to both County and City dispatch offices. The **M-1's** column refers to the total number of monthly M-1's which were issued on the M-1 days. The **M-1 hit** column refers to the number of issued M-1's which were verified by the occurrence of a heavy rainfall/flooding event, which met the M-1 criteria in **Table 3**. The **M-1 Red Flags (RF)** refers to the number of M-1's, which were "Red Flagged" by HMS meteorologists as meeting the Red Flag rainfall and timing criteria listed in **Table 3**. **M-1 RF hits** refers to the number of M-1 Red Flags, which were verified by heavy rainfall occurrence. The columns referring to Message 2 verification can be interpreted similarly.

Table 4: Monthly Message Verification for the 1999 F2P2 Operational Season

Month	M-1 Days	M-1 Day Hits	M-1's	M-1 Hits	% M-1 Hits	M-1 Red Flags	M-1 RF Hits	% RF Hits	M-2 Days	M-2 Day Hits	M-2's	M-2 Hits	% M-2 Hits
April	1	1	0	0	0	0	0	0	1	1	7	7	100
May	8	6	38	30	79	3	0	0	1	1	7	7	100
June	6	6	37	27	74	15	15	100	0	0	0	0	0
July	14	12	91	57	63	43	43	100	2	2	16	10	63
August	13	9	85	54	64	43	43	100	1	1	7	6	86
September	3	3	20	15	75	6	6	100	0	0	0	0	0
Totals	45	37	271	183	68	110	110	100	5	5	37	30	81

Message 1's were issued on a **total of 45 days well above the 21-year average** of 36 M-1 days. The **37 observed M-1 days were the third highest observed in the past 21 years**. In addition to the 44 M1 days, 5 Message 2 (M-2) days occurred in 1999. NWS issued all 5 of the 1999 Message 2's with HMS concurrence. Message 1's were issued on 2 of the 5 M-2 days.

In 1999 **68 percent of the 269 M1's verified which was 8 percent better than 1998 and 11 percent above the average**. *The 182 verified M1 events were the highest recorded since the F2P2 began.* A M1 Red Flag was issued 110 times and verified 110 times for the second straight

100 percent verification rate. The improvement in Red Flag (RF) verification marks the fourth straight year of 98 percent verification or better.

This consistent effort reverses the past concern that RF issuance was over-stimulated by the NWS WSR-88D Doppler radar and that customer RF expectations were not being met. HMS suggests that the four years of high Red Flag verification indicate this concern has been addressed and corrected.

Another notable achievement in 1999 was **improved** National Weather Service Flash Flood Watches or **Message 2 verification** in the F2P2. Five Message 2's or flash flood watches were issued in 1999 and flash flooding events were reported on all five of the days. **HMS and NWS concurred on all 5 Message 2's.** A total of 30 of 37 county/city combined M-2's verified by NWS criteria for an **accuracy of 81%.** This county/city M2 accuracy level for combined concurrence/non-concurrence days is the **highest** since records have been maintained (1990) by 18 percent. **This year marks the third straight year of improved flash flood watch verification.**

Message 3's (*Flash Flood Warning or Flood Warning*) were issued by the National Weather Service for **1 storm event and no M3's verified.** **HMS did not concur with the M-3 issuance on August 19. This M3 was issued based on radar and HMS believes that the radar over-estimated rainfall by a factor of two.** Close coordination between NWS and HMS meteorologists on storm days kept both organizations "on the same page" most days to the public's benefit.

The coordination was very timely during the intense onslaught of monsoon storms from July 19 to August 4th. Given the intense and frequent nature of the 1999 F2P2 season storms, anything less than close cooperation between HMS and NWS could have affected the performance of each agency. Instead, both groups benefited from each other's insight and expertise and provided outstanding support to the local populace during trying times.

4.2 County Message Verification and Service Evaluation

Each of the messages issued in the F2P2 is released to a specific county dispatcher in which the flooding potential has been forecast. Some of the Messages are issued for a portion of a county while others are issued for a specific basin supported by a Flood Detection Network (FDN). A County M-1 is verified as a **"hit"** only if a rain/flooding event meeting the M-1 criteria in Table 3 occurs in the **District portion** of that county. Verification for the City of Aurora was added to the County statistics this year. The same criteria apply for a Message issued for a basin-specific FDN. Messages are designed to support both the unique District flood-warning plans associated with Flood Detection Networks (FDN) and other portions of the counties and cities in the District, which do not have a FDN. Verification of each Message 1 by county provides a means of assessing the accuracy of the support given to these areas.

Improvement was noted in the accuracy of the County Message 1's issued during 1999 as seen in **Table 5.** Sixty-eight percent of the **County Messages verified which is an eight percent**

improvement over 1998. No events occurred without a prior Message and none were issued this year with less than 30 minutes lead-time.

Table 5: County M1 Verification for the 1999 F2P2 Operational Season

Month	M-1 Days	M-1 Day Hits	M-1	M-1 Hits	Cnty % Hits	Events Missed	Event< 10min Lead
April	1	1	0	0	0	0	0
May	8	6	38	30	79	0	0
June	6	6	37	27	74	0	0
July	14	12	91	57	63	0	0
August	13	9	85	54	64	0	0
September	3	3	20	15	75	0	0
Totals	45	37	271	183	68	0	0

Note: Table 5 does not include the 3 M-2 day statistics on which no M1's were issued

The overall 1999 improvement was also evident in **Message 1-Red Flag** issuance as evidenced in Table 6. A **Message 1** indicates to the user that **the potential exists for a flooding event** later during the day. A **Red Flagged Message 1** indicates that a **flooding event is imminent**. In other words the RED FLAG means rapid information dissemination and response action is needed. **One hundred percent of the 1999 Message 1's Red Flagged verified compared to 100 percent in 1998 and 99 percent in 1997**. The Red Flag verification rebounded to pre-1994 levels for the fourth straight year which indicates that **users can rely on it once again**.

Table 6: Verification for 1999 Red Flagged Message 1's

Group	M-1's	M-1 Hits	% M-1 Hits	Red Flags	RF Hits	% RF Hits	% RF M-1's
County							
ARAP	41	30	73	12	12	100	29
ADM	41	30	73	16	16	100	39
DUG	40	26	65	7	7	100	18
BOU	38	26	68	12	12	100	32
JEF	40	26	65	11	11	100	28
AUR	40	24	60	15	15	100	38
DEN	41	28	68	16	16	100	39
TOTAL	269	182	68	89	89	100	33
FDN PLANS							
ARV				8	8	100	100
LAK				7	7	100	100
WHT				6	6	100	100
TOTAL				21	21	100	100

5.0 Significant 1999 Storms

The 1999 F2P2 season began with a significant general rain event from **April 28 to May 1**, which brought minor flooding, and near 6 inches of rain to parts of Boulder County. Storm activity in May 1999 was more active than it had been for the past five years with five verified M-1 storm days. May 20 was the most active thunderstorm day with very active urban stream and street flooding noted in both Denver and Jefferson Counties.

Unlike most years strong storm activity in June occurred on only five days in the middle of the month. This year marks the third straight year that June thunderstorm activity was not as intense as storm, which occurred during July and August. A particularly intense storm developed over northern Douglas County **on June 11** and moved to the southeast into Elbert County. Along the way this storm dropped almost a foot of 0.50" to 1.00" diameter hail near Franktown and Larkspur just outside the District boundaries. The cities of Denver and Aurora joined Douglas County in experiencing minor street flooding problems on this day.

Twelve flash flooding event days occurred during July as the summer monsoon season began. Multiple day minor street flooding episodes occurred **7-8 July, 16-19 July and 25-31 July**. While storm activity was troublesome on each of these days, the worst storms focused on the end of the month.

On **July 28th** a series of very strong thunderstorms developed in both the foothills and on the plains. In the District eastern Denver and most of Aurora were pelted with "front-end" dumper rains of over 1.00"/20 minutes with up to 1.73" in total rainfall observed in Aurora. Heavy thunderstorms produced minor street flooding in Wheat Ridge and Arvada. During the height of the storm the District Flood Prediction Center's building was struck by lightning, which took power off line to the entire building including phone lines. HMS meteorologists continued to provide remote support. In all eight Red Flags were issued and verified. The severity of the storms and the intensity of the rainfall was unscored by a massive mudslide on I-70 just east of the Eisenhower Tunnel, which closed the interstate for 25 hours.

A second round of very heavy rainfall struck the District on **July 31** especially hard in northeast Denver and northern Aurora. Over eight gauges in the District's Flood Detection Network recorded over an inch of rain with 1.69" in Aurora the heaviest amount. HMS meteorologists provided service without access to the NWS WSR-88D radar for this event by using Internet dial-up sources and "a good old fashioned metwatch out the window". Years of operational support and experience paid off in dividends as 15 of 21 individual M-1's and Red Flags verified despite the lack of radar data.

The nastiest flood day of the 1999 F2P2 occurred on August 4, 1999. Serious flash flooding occurred in Jefferson County on Massey Draw just north of Chatfield Reservoir, and in Adams County on I-25 from 104th to 144th where I-25 was closed for a period of time and in Westminster and Federal Heights in northeastern Jefferson County. Rainfall re-construction of the Massey Draw storm

indicated thunderstorm produced rainfall of 3-5 inches across the basin between 430PM and 630PM which was followed by a general basin rain of 1-2 additional inches bringing the peak storm rainfall over 0.5 square miles to just over 7 inches. Basin average rainfall was about 3.50 inches for the 12-hour storm period.

While a reconstruction was not accomplished on the Westminster and Federal Heights storm, it is estimated that a general 2-3 inches of rain fell on the basin with peak point rainfall possibly approaching 4-5 inches. Both this storm and the Massey Draw storm were spawned by a massive Denver Cyclone, which formed over western Denver and eastern Jefferson Counties between 3PM and 4PM. The District was very fortunate that the "Denver Cyclone split" into two smaller systems that created the Massey Draw storm and the Westminster storm. Had this mesoscale system maintained and focused its rainfall potential over one basin or community, the District might have experienced the flooding disaster it has evaded for the past 21 years.

The monsoon finished with a flourish of storm activity from **August 27th through September 3rd** with almost daily storms and street flooding potential. While no major flash flood occurred during this period, 19 Red Flags were issued and verified as almost daily nuisance street flooding was reported.

These storms were the most notable of the 1999 F2P2 in the opinion of the HMS staff. It is certain that other storm days could have been included based on peak stream flows reported, intensity of attendant severe weather, vicious lightning or the potential for a major flooding event. Note the predominance of strong storms the past three years in the rapidly populating areas of the eastern District in Adams, Arapahoe and Douglas Counties. ***Six Message 1's and three Red Flags were issued for the Denver International Airport during the season, which is the most on record for this area.*** The significant increase in overnight hours the past three years has been a growing concern of HMS meteorologists as newly populated areas of the eastern District are exposed to periods of monsoon nocturnal storms. We believe that a review of the population in newly develop subdivisions would assist forecasters in supporting these eastern areas of the District.

6.0 Concerns and Recommendations

HMS utilizes this portion of the report to identify important operational developments, operational problem areas and matters of concern, which became apparent during the operational season.

Mesonet

HMS meteorologists have been very pleased with continued upgrading of weather station coverage by the District during the 1999 F2P2. The addition of weather station sites in Douglas, Adams and Boulder Counties vastly improved HMS capability to issue basin-specific products such as QPF and StormTraks. HMS supports new weather stations at DIA and Aurora Reservoir in the eastern District to address the expanding population base, a new flood detection network in the southwestern corner of the District where a "data-void area" has existed and on Squaw Peak to assist in the use of mesosounds to address storm capping by inversion problems.

Training

HMS continues to note the 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. HMS feels strongly that the training issue is a very necessary component of a successful flash flood warning program. The concerns are based on turn over at dispatch locations. Our suggestions are:

1. **Provide direct person-to-person contact between dispatchers and decision-makers and HMS meteorologists to discuss communications and decision-making issues. Provide training to dispatchers and decision-makers in use of District F2P2 products and in exercises.**
2. **Exercise existing flood warning plans, and makes suggestions on how they can be improved.**

HMS meteorologists have not visited the supported agencies en-masse for several years and planned F2P2 user days and Media F2P2 days have been poorly attended. HMS feels that the personal contact is needed to keep emergency response agencies motivated and able to respond in case of a major urban or foothills flash flood. Additionally HMS recommends that exercises based on the Fort Collins and Big Thompson events should be developed for the urban and foothills areas respectively.

Use of the Internet

HMS recommends that the District aggressively pursue an inventory of F2P2 users to determine if Internet delivery of most F2P2 products would satisfy user needs and offer new venues of user support. Increasing costs of Broadcast fax services and "the paper bound format" of QPF, Message and StormTrak products could be released into a more graphic user-friendly context.

Flood Warning Plans

HMS suggests that the District consider assisting local communities without flood detection networks to develop and exercise community-specific flood warning response plans. The need would appear most acute in the Jefferson and Boulder County foothills where many new communities are developing. Additional need areas may be located in rapidly developing and previously rural land around DIA and in unincorporated portions of Douglas, Arapahoe and Adams Counties.

Recommendations

HMS offers the following recommendations for consideration by the District in 1999:

1. **HMS recommends that the District consider the development of flood warning response plans for urban and foothills areas of Jefferson, Douglas, Boulder, Adams and Arapahoe Counties where rapidly growing communities have formed and flood detection networks and flood warning plans do not yet exist.**
2. **HMS recommends the continued effort to expand the District ALERT Mesonet to assist in the production of basin-specific Message, StormTrak and QPF products.**
3. **HMS recommends an inventory of F2P2 users to identify the potential of using the Internet for F2P2 delivery of F2P2 forecast products, including Messages, in graphic formats.**

APPENDIX A

1998

COUNTY AND CITY

DAILY MESSAGE VERIFICATION

Table A-1: Verification of All 1998 Message 1's (Bolded "H's" indicate Red Flag days)

Date	ARP	ADM	DUG	BOU	JEF	DEN	AUR	LAK	WHT	ARV	H	M
5/21	M	M				M	M				0	4
5/22	H	H	H	M	M	H	H				5	2
5/24				NMNI	NMNI							
5/29	H	M	M	M	H	M	M				2	5
H	2	1	1	0	1	1	1				7	
M	1	2	1	2	1	2	2					11
Date	ARP	ADM	DUG	BOU	JEF	DEN	AUR	LAK	WHT	ARV	H	M
6/2	M	H	M	H	H	H	M				4	3
6/6	H	H	M	H	H	H	H	H	H	H	9	1
6/7	H	H	H	M	M	M					3	3
6/8	H	H	M	H	H	H	M	HR			6	2
6/9	M2M	M2M	M2M	M2H	M2H	M2M	M2M					
6/10	H	H	H	M	H	H	H	2HR	HR		8	1
6/12	HR	H		H	M	H	HR				5	1
6/13	H	H	H	H	H	H	H				7	0
6/14	H	H	H	M	H	H	H	HR	HR		8	1
6/15		H		M							1	1
6/18	H		M				H				2	1
6/21				H	H						2	0
6/23	H	M	M		M	H	H				3	3
6/25	H	H	M	H	H	H	HR		HR	HR	8	1
H	10	10	4	7	8	9	8	4	4	2	66	
M	1	1	6	4	3	1	2	0	0	0		18
Date	ARP	ADM	DUG	BOU	JEF	DEN	AUR	LAK	WHT	ARV	H	M
7/19	HR	HR	HR	H	H	HR	HR				7	0
7/19		M3H				M3H	M3H					
7/20	M	M	M	M	M	M	M				0	7
7/21	H	M	H			H					3	1
7/23		H		H							2	0
7/24	H	H	H	M		H	H				5	1
7/25	HR	M	H	M	HR	HR	HR	HR			6	2
7/27	HR	M	2HR	M	HR	HR	HR	2HR	HR	HR	8	2
7/27					M3M							
7/28	HR	HR	H	H	2HR	HR	HR				7	0
7/28	M2HR		M2M	M2HR		M2M	M2HR		M2M			
7/29	M2M	M2M	M2HR	M2M	M2H	M2M	M2M					
7/30AM	M2M		M2H									
7/30	M	HR	H	HR	HR	M	M			HR	5	3
7/30PM	M2HR	M2HR	M2HR	M2HR	M2HR	M2HR	M2HR		M2HR	M2HR		
7/30	M3HR			M3H	M3H	2M3HR	M3H					
7/31	M2HR	M2M	M2HR	M2M	M2H	M2HR	M2HR					
H	6	5	7	4	5	6	5	2	1	2	43	
M	2	4	1	4	1	2	2	0	0	0		16

4Legend

ARP: Arapahoe County

ADM: Adams County

DUG: Douglas County

BOU: Boulder County

JEF: Jefferson County

DEN: Denver County

AUR: Aurora

LAK: Lakewood

WHT: Wheat Ridge

H = M-1 which verifies or hits

M = M-1 which does not verify or misses

HR = M-1, Red Flag which verifies

M2M = NWS M-2 which does not verify

MR = M-1, Red Flag which does not verify

0 = M1 with low lead time as in **HR0**

M2H = NWS Message 2 which verified

M3H = NWS Message which verified

M3M = a NWS M3 which did not verify

ARV: Arvada

Date	ARP	ADM	DUG	BOU	JEF	DEN	AUR	LAK	WHT	ARV	H	M
8/01	M	HR	M	M	HR	HR	M	HR	HR		5	4
8/02	HR	HR	M			HR					3	1
8/03					HR	M		HR	HR		3	1
8/04	M2HR	2M2HR	M2HR	M2HR	M2HR	2M2HR	M2M	M2HR	M2HR	M2HR		
8/05	M2H	M2H	M2M	M2H	M2H	M2H	M2H					
8/06	M2M	M2H	M2M	M2M	M2M	M2M	M2M					
8/11	HR	H	HR		HR	HR	HR	HR			7	0
8/12	H	H	H	H	2HR	2HR	HR			MR	7	1
8/16	HR	HR	M	H	H	M	HR				5	2
8/17	M	H	M	H	H	M	M				3	4
8/18	HR	HR	HR	H	HR	M				HR	6	1
8/21				H	H						2	0
8/26	H	H	H	M	H	M	H				5	2
8/28	H	M	M	H	H	H	H				5	2
8/31	H	M	HR		M	H	M				3	3
H	8	8	5	6	10	6	5	3	2	1	54	
M	2	2	5	2	1	5	3	0	0	1		21
Date	ARP	ADM	DUG	BOU	JEF	DEN	AUR	LAK	WHT	ARV	H	M
9/01	M	H	M	H	H	H	M				4	3
9/03	HR		HR		HR	HR	M				4	1
9/04	H	H	H	H	H	H	H				7	0
9/06	M	H	H	H	M	M	M				3	4
9/11	H										1	0
H	3	3	3	3	3	3	1	0	0	0	19	
M	2	0	1	0	1	1	3	0	0	0		8
TOTAL M1 H	27	25	20	20	25	24	20	8	7	5	181	
TOTAL M1 M	8	9	12	10	7	10	11	0	0	1		68
TOTAL M1	35	34	32	30	32	34	31	8	7	6		249

ARP: Arapahoe County
ADM: Adams County
DUG: Douglas County
BOU: Boulder County
JEF: Jefferson County
DEN: Denver County
AUR: Aurora
LAK: Lakewood
WHT: Wheat Ridge
ARV: Arvada

Legend

H = M-1 which verifies or hits
M = M-1 which does not verify or misses
HR = M-1, Red Flag which verifies
M2M = NWS M-2 which does not verify
MR = M-1, Red Flag which does not verify
0 = M1 with low lead time as in **HR0**
M2H = NWS Message 2 which verified
M3H = NWS Message which verified
M3M = a NWS M3 which did not verify

APPENDIX B

SUPPLEMENTARY ANNUAL VERIFICATIONS

Internal Use Only

Table B-1
UDFCD F2P2 DISTRICT-WIDE MESSAGE 1 DAY ONLY VERIFICATION
1979 - 1998

	Year	Message 1 Days	Verified Hits	Verified Misses	Not Forecasted	Percent Accuracy	False Alarm %	Probability of Detection
GRD Weather Center District Era	1979	26	17	9	3	65%	35%	85%
	1980	35	23	12	0	66%	34%	100%
	1981	40	31	9	0	78%	23%	100%
	1982	42	34	8	0	81%	19%	100%
Henz, Kelly & Assoc. County Era	1983	37	32	5	0	86%	14%	100%
	1984	38	32	6	0	84%	16%	100%
	1985	28	25	3	0	89%	11%	100%
	1986	35	30	5	1	86%	14%	97%
	1987	47	40	7	0	85%	15%	100%
	1988	28	24	4	0	86%	14%	100%
	1989	31	26	5	0	84%	16%	100%
HMS Red Flag Era	1990	30	26	4	2	87%	13%	93%
	1991	42	31	11	0	74%	26%	100%
	1992	29	25	4	0	86%	14%	100%
	1993	28	25	3	0	89%	11%	100%
	1994	26	24	2	0	92%	8%	100%
	1995	43	35	8	1	81%	19%	97%
	1996	52	41	11	0	79%	21%	100%
	1997	40	38	2	1	95%	5%	97%
	1998							
	1999							
Total District Era		143	105	38	3	73%	27%	97.2%
Total County Era		244	209	35	1	86%	14%	99.5%
Total Red Flag Era		290	245	43	4	84%	16%	98.4%
Total		677	559	116	8	82%	18%	98.7%
19 Year Average		36	29	11	0.4	82%	18%	98.5%

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

Hit = Verification of Message in District

Miss = No Verif.

Table B-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
1991	42	31	11	74%	26%	100%	293	155	138	53%
1992	29	25	4	86%	14%	100%	143	81	62	57%
1993	28	25	3	89%	11%	100%	123	66	57	54%
1994	26	24	2	92%	8%	100%	153	86	67	56%
1995	43	35	8	81%	19%	98%	283	159	124	56%
1996	52	41	11	79%	21%	100%	267	173	94	65%
1998	40	38	2	95%	5%	100%	249	181	68	73%
Tot	260	219	41	84%	16%	99%	1513	898	615	59%
Avg	37	30	6	83%	17%	100%	210	120	90	57%

Table B-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%
1993	123	66	54%	100	60	60%	23	6	26%
1994	153	86	56%	112	70	63%	41	16	39%
1995	283	159	56%	197	118	60%	86	41	48%
1996	267	173	65%	215	132	61%	52	41	79%
1998	249	181	73%	197	141	72%	52	40	77%
Total	1511	901	60%	1115	685	61%	396	216	55%

Table B-4: Red Flagged M-1's (RF)

Year	Total M-1's	RF's	RF Hits	Percent RF Hits	Percent RF's	County RF's	County RF Hits	% County RF Hits	City RF's	City RF Hits	% City RF Hits
1991	293	171	156	91%	58%	N/A	N/A	N/A	N/A	N/A	N/A
1992	143	85	81	95%	59%	69	66	97%	16	15	94%
1993	123	12	12	100%	10%	8	8	100%	2	2	100%
1994	153	67	47	70%	44%	38	32	84%	29	15	52%
1995	283	159	110	69%	56%	92	76	83%	66	34	52%
1996	267	107	105	98%	40%	73	72	99%	34	33	97%
1998	249	96	95	99%	38%	65	65	100%	31	30	97%
Tot	1511	697	606	87%	46%	345	319	92%	178	129	72%