2002
UDFCD FLASH FLOOD PREDICTION PROGRAM ANNUAL REPORT

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Pyro Cumulonimbus Cloud over the Hayman Burn Area June 10, 2002.

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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 District contracts the unique, basin/storm-specific weather prediction services of a Private Meteorological Service (PMS) to augment the traditional forecast and warning services of the National Weather Service (NWS) for the seven-county District area.

The District forecast area supported by the PMS is shown in Figure 1 and includes over 60 percent of Colorado's population. The District is approximately 1,600 square miles and the forecast area is about 3,000 square miles that includes the upper basin areas of streams that flow into the District. Terrain in the forecast area 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 dramatically over the last few years with most notable increases occurring within the city of Aurora and Douglas County. Douglas County has been one of the fastest growing Counties in the United States over the last four years. The incorporation of Broomfield County in late 2001 has brought the number of counties within the District to seven.

HDR Hydro-Meteorological Services of Denver was selected as the 2002 F2P2 PMS. HDR operational meteorologists Robert Rahrs, Bryan Rappolt, John Henz and William Badini provided the F2P2 forecast services with the assistance of meteorological technician Daniel Henz. Bryan Rappolt acted as Project Manager and John Henz provided quality control and quality assurance on F2P2 products and provided guidance to the on-duty operational meteorologist, based on his vast experience with the F2P2.

This season marked the first for Robert Rahrs working within the F2P2. Bryan Rappolt worked his 11th season on the F2P2 while Bill Badini worked his 4th and Daniel Henz his 2nd. John Henz's participation in the program this season marked his 24th year being involved with the F2P2.

2.0 2002 Operational Season

The 2002 F2P2 season began on April 15 and concluded on September 15 for a total of 154 operational days. Normal operational hours were from 0700 to 2200 which accounted for 2,310 hours. During the time period from 2200 to 0700 HDR meteorologists and meteorological technicians provided an additional 275 hours of support time as thunderstorms affected the District or the potential existed for the development of thunderstorms that could affect the District.

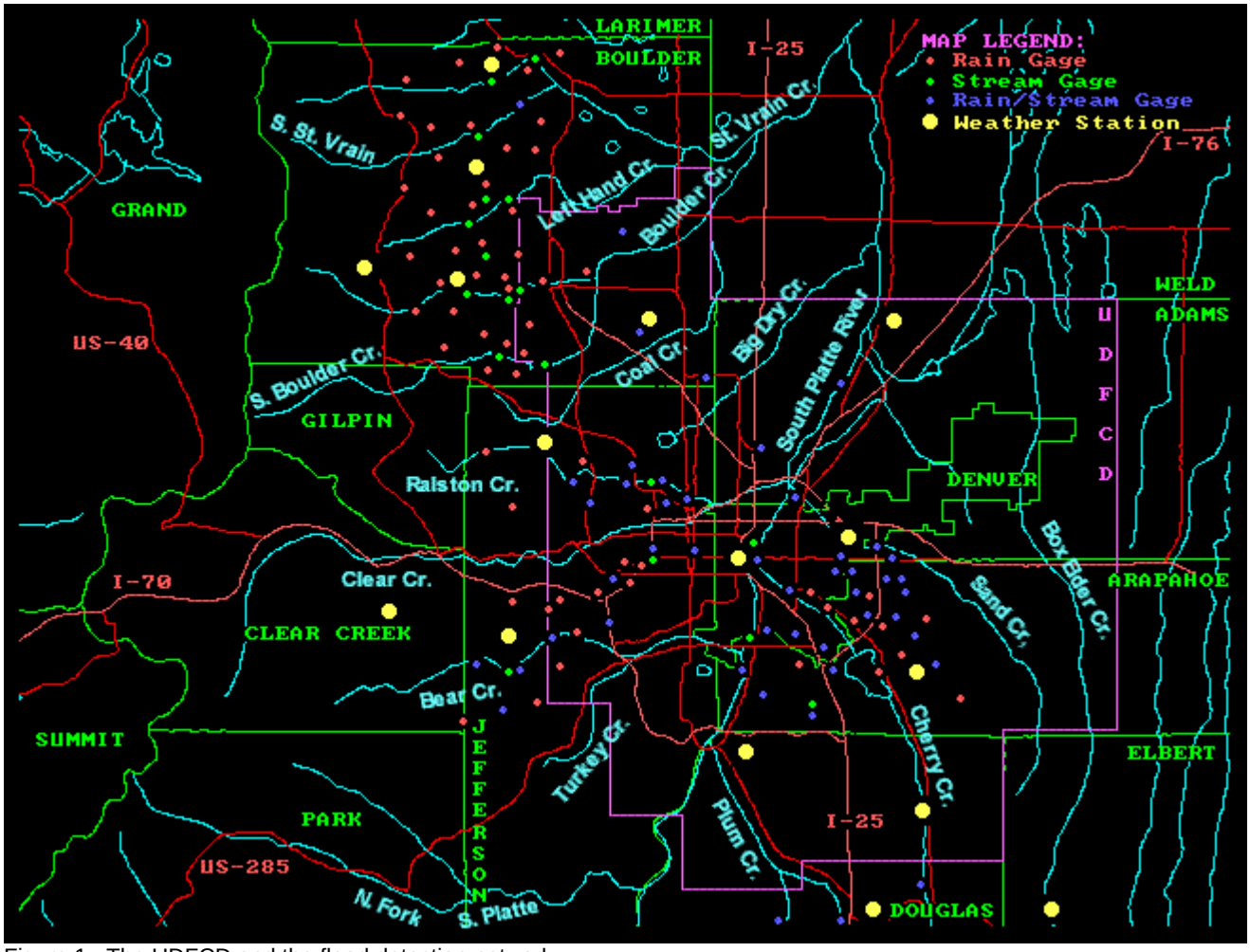

Figure 1. The UDFCD and the flood detection network.

3.0 2002 F2P2 Operational Products

The F2P2 is designed to offer a unique, rainfall prediction and warning service concerning, urban flooding and flash flooding threats to the seven District counties and the cities and towns within those counties. Direct support is rendered to the District basin-specific warning plans identified below:

1. **Boulder Creek Flood Warning Plan**, which serves Boulder/South Boulder Creeks in Boulder County, which impacts the City of Boulder and portions of un-incorporated Boulder County.
2. **Lena Gulch Flood Warning Plan**, which serves the Lena Gulch Basin and impacts Jefferson County, Golden, Lakewood and Wheat Ridge.
3. **Goldsmith/Harvard Gulch Flood Warning Plan** which impacts south-central Denver.
4. **Westerly Creek Flood Warning Plan**, which impacts eastern Denver and western Aurora.

5. **Toll Gate Creek Flood Warning Plan**, which impacts central and southern Aurora.
6. **Ralston Creek Flood Warning Plan**, which impacts Arvada and Jefferson County.
7. **Bear Creek Flood Warning Plan**, which impacts western Lakewood, the town of Morrison and portions of central Jefferson County.

Five specific F2P2 products were produced by HDR meteorologists. These products included the Heavy Precipitation Outlook (HPO), Messages, Internal Message Status (IMS), Quantitative Precipitation Forecasts (QPF) and StormTrak. During the 2002 season HDR produced the following number of F2P2 products:

Table 1: 2002 F2P2 Product Summary

Product	Number issued
Heavy Precipitation Outlook (HPO)	**254**
Message and Message Updates	**392**
Internal Message Status (IMS) reports	**69**
Basin-Specific Quantitative Precipitation Forecasts	**26**
StormTraks	**61**
Total	**771**

All products were delivered to F2P2 participants using Xpedite Internet-based broadcast fax service and were also uploaded and available from UDFCD's ALERT web site, http://alert.udfcd.org/udebb.html. Message forms were the only F2P2 product not available on the UDFCD's ALERT web site due to the fact that Messages (internal alerts) are only intended to be utilized by F2P2 participants and are not intended for the public.

Voice communication continues to be the primary form of communication within the F2P2. Three hundred thirty five (335) telephone interactions were logged by HDR, between HDR meteorologists/meteorological technicians and F2P2 participants, emphasizing the strong personal touch of the program.

Denver Office of Emergency Management and Denver Wastewater received notification of the issuance of Messages and StormTraks through pagers. Inforad software was used to disseminate the text information to the pagers. There were a total of 84 information disseminations to the Denver F2P2 pager network.

4.0 2002 F2P2 Operational Verification

The primary service rendered by the F2P2 to participants is the issuance of forecasts of flash flooding potential, urban and stream flooding, and locally heavy rainfall events that cause nuisance flooding. HDR indicates the potential for these events in a series of products issued directly to the users by phone, fax and Internet. The definition and criteria associated with each Message is given in Table 2.

The issuance of F2P2 Messages is quantitatively linked to rainfall criteria established by the District.

Table 2: UDFCD Flash Flood Prediction Program Message Criteria

UDFCD FLASH FLOOD PREDICTION PROGRAM
MESSAGE CRITERIA

Message 1: **M-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 significant. 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** **RED FLAG** **Rainfall intensity**:	Issued to identify storm events, which fall just short of producing life-threatening rainfall, but produce significant runoff. Rainfall rates are predicted or observed to **equal** or **exceed 1.00"/30** minutes **and** the storm is considered **imminent**.

Message 2: **M-2**	Issued when the threat of potential life threatening flooding is predicted or the NWS issues a Flash Flood Watch. An HDR-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 HDR due to antecedent rainfall impacts on soil saturation and/or runoff characteristics.**

Message 3: **M-3**	Issued when 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.
Message 4:	Issued when the flooding threat has passed.

4.1 Message Verification

The verification of the Messages issued by HDR meteorologists is presented in Table 3. A Message day is defined as any day from April 15 to September 15 on which a Message 1, Message 2 or Message 3 is issued based on the criteria presented in Table 2. Messages were issued on 23 days during the 2002 F2P2. There were 16 days, of the 23 that at least one Message that was issued verified, based on the established criteria listed in Table 2. The result was a 70 % verification of messages days on a District-wide basis.

Table 3: Monthly Message Verification for the 2002 F2P2 Operational Season

Month	District-Wide Message Days	District-Wide Message Days Verified	City/County Messages Issued	Messages Verified	Percent of Message Days Verifying
April	0	0	0	0	N/A
May	0	0	0	0	N/A
June	4	2	28	11	50%
July	7	5	45	22	71%
August	7	7	56	33	100%
September	5	2	35	15	40%
Total	**23**	**16**	**164**	**81**	**70%**

Message 1's were issued on 23 days, which tied for the 1st lowest number of Message days in the 24-year history of the F2P2. The other year in which only 23 Message 1's were issued was in 2000.

No Flash Flood Watches or Message 2's were issued for any portions of the district during the 2002 operational season. This is the lowest number of Message 2's in the 24-year history of the F2P2.

Two Flash Flood Warnings were issued by the National Weather Service during the 2002 operational season. The first warning was issued for southwestern Denver County, and eastern Jefferson County at 1204 AM on July 3rd. HDR issued a Message 3 to southwest Denver and east central Jefferson Counties, but did not concur with the warning. Only minor street flooding was reported in the warning area.

The second Flash Flood Warning was issued for Adams county and northeast Denver County, specifically Denver International Airport, during the afternoon of August 5. HDR issued a Message 3 to Denver and Adams Counties, and did concur with the warning. Flash flooding was observed across a portion of the warned area, as significant flooding of low-lying areas was observed due to an

estimated 2.50 to 3.00” of rainfall that occurred in a 60-75 minute period. The heavy rainfall was associated with two separate thunderstorms cells that tracked over the same area.

4.2 County/City Message Verification and Comparison Statistics

Each Message issued in the F2P2 is disseminated to a specific county or city in which flooding potential has been forecast. These counties and cities are listed in Table 4. A Message indicates to the user that the potential exists for a flooding event later during the day. A Red Flag indicates that flooding event is imminent. In other words, the Red Flag means rapid information dissemination and response action is needed by emergency response agencies.

A Red Flag Message 1 was issued 36 times and verified 36 times for a 100 percent verification rate. This marks the seventh straight year the Message 1 Red Flag has had verification of 98 percent or better. The Red Flag Message 1 has proved to be one of the most reliable products within the F2P2.

A County Message is verified as a "hit" only if a rainfall event meeting the Message criteria in Table 2 occurs in the District-portion of that city/county or in the drainage area of a stream that flows into the District. Table 4 below summarizes the results of the 2002 F2P2 verification by jurisdiction.

Verification for the City of Aurora is included in the County statistics because Aurora is a primary contact point. The cities of Arvada, Lakewood and Wheat Ridge receive Message notifications from Jefferson county dispatchers while Red Flag notifications are received from both HDR meteorologists and Jefferson county dispatchers. Messages and Red Flags are designed to support both unique District flood-warning plans associated with Flood Detection Networks (FDN) and other portions of District counties and cities that do not have a flood detection network. A table listing the days that messages and Red Flags were issued, verification of the messages and red flags, and the city and/or county they were issued for can be found in Appendix A.

Table 4: County/City Message Verification for the 2002 F2P2 Operational Season

Primary Contacts	Messages Issued	Message Hits	% Message Hits	Red Flags Issued	Red Flag Hits	% Message Red Flag Hits	Events Missed	Event < 10min Lead Time
Arapahoe	21	13	62	5	5	100	0	0
Adams	20	9	45	3	3	100	0	0
Douglas	23	14	61	6	6	100	0	0
Boulder	19	5	26	4	4	100	0	0
Jefferson	23	13	56	3	3	100	0	0
Aurora	21	10	48	5	5	100	0	0
Denver	23	11	48	5	5	100	0	0
Broomfield	18	8	44	2	2	100	0	0
TOTAL	**168**	**83**	**49**	**33**	**33**	**100**	**0**	
Red Flag Only Contacts	**Messages Issued**	**Message Hits**	**% Message Hits**	**Red Flags Issued**	**Red Flag Hits**	**% Message Red Flag Hits**	**Events Missed**	**Event < 10min Lead Time**
Arvada	N/A	N/A	N/A	1	1	100	0	0
Lakewood	N/A	N/A	N/A	1	1	100	0	0
Wheat Ridge	N/A	N/A	N/A	1	1	100	0	0
TOTAL	**N/A**	**N/A**	**N/A**	**3**	**3**	**100**	**0**	**0**
GRAND TOTAL	**168**	**83**	**49**	**36**	**36**	**100**	**0**	**0**

Here is a sampling of how the 2002 F2P2 season ranks against the prior 23 F2P2 seasons:

1. **Tied for lowest number of Message days (23). The other year with the lowest number of Message days (23) was 2000.**
2. **Tied for the highest percentage of Red Fag verifications (100%).**
3. **Least number of Message 2's and National Weather Service Flash Flood Watches (0).**

Message statistics for the all 24 F2P2 seasons can be found in a table located in Appendix B.

5.0 Significant weather events: The "Drought and Wildfire" summer

A lack of significant snowfall during the winter of 2001/2002 and the lack of rainfall during the spring of 2002 across Colorado resulted in precipitation across the District being well below normal. The dry conditions resulted in extremely high fire danger across the District and all of Colorado. Numerous wildfires were observed during the summer of 2002 with the most notable being the Hayman Fire across east central Colorado, the Missionary Ridge Fire in southwest Colorado and the Coal Seam Fire in west central Colorado. Numerous other wildfires were observed across the state as well.

The Hayman Fire started on June 8, 2002 in northeast Park County and quickly spread into southern Jefferson, southwest Douglas, and northwest Teller counties. The fire did not burn any portion of the F2P2 forecast area, however its associated smoke plume did move over the District when lower atmospheric winds were of a southerly component.
Smoke, associated with other wildfires, across Colorado, Wyoming, Utah, and Idaho also moved over the District occasionally throughout the summer.

A few of the more significant "storm events" in the 2002 F2P2 are listed below:

August 5: Multiple thunderstorms moved over areas just east of Denver International Airport and west central Adams County. Very heavy rainfall of 2.23" was observed by an ALERT rain gage located on Third Creek, near DIA in about a 75-minute period. A stream gage located on Third Creek, near DIA, set a record high water level for the 2-year-old ALERT stream gage.

August 27: Multiple thunderstorms developed across east central Douglas and west central Elbert county during the early morning hours. Very heavy rainfall is estimated to have fallen over the upper portion of the Cherry Creek and West Cherry Creek drainage basins, between the towns of Franktown and Elbert. A rather significant hydrologic event was observed on Cherry Creek, in northern Franktown. An ALERT stream gage located at Cherry Creek and Castle Oaks Road observed a peak stage of 7.2 feet around 430 AM; eclipsing the previous record high observed stage of 5.2 feet on April 30, 1999. This rainfall event is currently being reconstructed by HDR Hydro-Meteorological Services, and should be completed in March, 2003.

August 29: A thunderstorm produced multiple tornadoes across southeast Aurora and northeast Douglas County. Significant damage was observed across a southeast Aurora sub-division where condominiums were being constructed. Heavy rainfall and subsequent street and low lying area flooding was observed across Douglas, Arapahoe, Denver, Jefferson and Adams counties.

Figure 2: Tornado in Southeast Aurora


Figure 3: Tornado in Southeast Aurora

September 12 and 13: Late afternoon summer thunderstorms on both of these days produced significant street flooding. On September 13, one small intense thunderstorm developed over Denver county and tracked towards the southeast through Aurora, Arapahoe, and Douglas counties. This storm produced 1.00-1.25" of rainfall over a 20-30 minute period that resulted in significant flooding on Interstate 25 under the Logan Street Bridge. Numerous people had to be rescued from their flooded automobiles.


Figure 4: Flooding on I-25 at Logan

6.0 Recommendations

HDR 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.

ALERT Mesonet

HDR is pleased with continued upgrading of the District ALERT weather station network. The Urban Farm weather station was installed late in the 2001 F2P2 season and was deemed valuable in determining the rainfall potential across northeast Denver County.

An ALERT weather station was installed, and is now operational, along the north side of Marston Lake in southwest Denver County. Although this weather station will help to determine rainfall potential across the southwest portion of the district in the future, it was installed too late to be utilized operationally within the 2002 season.

The expected installation of an ALERT weather station at Aurora Reservoir for the 2003 season will be valuable for determining the rainfall potential across eastern Aurora.

The installation of additional ALERT weather stations in Weld County, eastern Arapahoe and Adams Counties will help with timing the arrival and the temperature/moisture content of thunderstorm outflow boundaries that can have an impact of the District.

Xpedite Internet-based broadcast fax service

HDR has embraced the Xpedite Internet-based broadcast fax delivery service of F2P2 products and recommends it be used again next year. However a backup service needs to be put in place that could be utilized if the Xpedite service is not working. It is suggested that an Internet-based fax delivery service, similar to Xpedite be subscribed to, but only utilized if the Xpedite service is not working.

Internet Access

HDR suggests that the District provide an alternate source for access to the Internet as back-up to the existing access to the Internet that is currently provided within the Flood Prediction Center. At a minimum the speed of the alternate source of Internet access needs to be 128 kb/sec.

Internet access is critical to the PMS to access meteorological information to develop F2P2 products and to desiminate F2P2 products using Xpedite.

Flood Warning Plans

HDR suggests that cities and counties served by the F2P2 should develop GIS-based Flood Response Plans (FRP) that can be used in concert with existing District Flood Warning plans and information. The FRP's may assist emergency response agencies in pro-active response actions and coordination by enhancing the existing District Flood Warning Plans.

QCP2 and QRPM

HDR suggests that the Quantitative Convective Precipitation Potential (QCP2) and the Quantitative Radar Precipitation Mapping (QRPM) products, developed in an earlier contracting effort between HDR, Brown and Caldwell and the District, be utilized during the 2003 F2P2.

The QCP2 product estimates potential rainfall amounts over the entire district using the ALERT weather station information and HDR meteorologist's rainfall prediction algorithm. The QCP2 should assists F2P2 forecasters in the assessment of heavy rainfall and the development quantitative precipitation forecasts for District basins and sub-basins.

The QRPM product estimates observed rainfall amounts using the ALERT weather station information and GIS-based Doppler Radar Reflectivity. The QRPM should assists F2P2 forecasters in Message verification, especially across portions of the district that are not representative of a nearby ALERT rain gage.

APPENDIX A

Appendix A
2002 F2P2 Verification of Messages and Red Flag Messages

#	Date	Arapco	Adco	Boco	Denco	Dougco	Jeffco	Aurora	Brmco	Red Flag	Lak	Arv	Arapco	Adco	Boco	Denco	Dougco	Jeffco	Aurora	WhtRg	Brmco
1	6/03	HIT	HIT	HIT	HIT	HIT	MISS	HIT	HIT						HIT						
2	6/04	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
3	6/19	HIT			HIT	HIT		HIT									HIT				
4	6/20	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
5	7/03	HIT	HIT	MISS	MISS/ MISS*	HIT	HIT/MISS*	MISS	MISS												
6	7/04	HIT	MISS		MISS	HIT	HIT	MISS													
7	7/05	HIT			HIT	HIT	HIT	HIT													
8	7/06	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
9	7/10	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT				HIT	HIT	HIT	HIT	HIT	HIT	HIT		HIT
10	7/21					HIT	HIT											HIT			
11	7/22	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
12	8/4	HIT	HIT	MISS	HIT	HIT	HIT	MISS	HIT												
13	8/5	HIT	HIT/HIT**	HIT	HIT/HIT**	HIT	HIT	HIT	HIT		HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT
14	8/6	MISS	MISS	MISS	MISS	MISS	HIT	MISS	MISS												
15	8/20	MISS	MISS	HIT	MISS	MISS	MISS	MISS	HIT												
16	8/27	HIT	MISS	MISS	HIT	HIT	HIT	HIT	MISS								HIT				
17	8/28	HIT	MISS	MISS	MISS	HIT	HIT	HIT	MISS												
18	8/29	HIT	HIT	MISS	HIT	HIT	HIT	HIT	HIT				HIT	HIT		HIT			HIT		
19	9/8			MISS		MISS	MISS														
20	9/9	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
21	9/11	MISS	MISS	MISS	MISS	MISS	MISS	MISS	MISS												
22	9/12	HIT	HIT	HIT	HIT	HIT	HIT	HIT	HIT				HIT		HIT	HIT	HIT		HIT		
23	9/13	HIT	HIT	MISS	HIT	HIT	HIT	HIT	HIT				HIT			HIT	HIT		HIT		
HIT/TOT		13/21	9/20	5/19	11/23	14/23	13/23	10/21	8/18		1/1	1/1	5/5	3/3	4/4	5/5	6/6	3/3	5/5	1/1	2/2
% Hit		**62**	**45**	**26**	**48**	**61**	**59**	**48**	**44**		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Message day hits: 16/23 70 %

“Bust days”: 7

Message 2’s: 0

Message 3’s: 2: 1 non-concurrence on 7/3 (Jeffco* and Denco*) and 1 concurrence on 8/5 (Adco and Denco**).**

APPENDIX B

Appendix B

UDFCD F2P2 DISTRICT-WIDE MESSAGE 1 DAY STATISTICS

1979 - 2002

	Year	Message 1 Days	Verified Hits	Verified Misses	Not Forecasted	Percent Accuracy	False Alarm %	Probability of Detection
GRD "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%
HKA "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 "Basin" 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	34	28	6	0	82%	18%	100%
	1999	45	37	8	0	82%	18%	100%
	2000	23	19	4	1	83%	17%	95%
HDR HDR	2001	42	39	3	0	93%	7%	100%
	2002	23	16	7	0	70%	30%	100%
	Total District Era	**143**	**105**	**38**	**3**	**73%**	**27%**	**97.2%**
	Total County Era	**244**	**209**	**35**	**1**	**86%**	**14%**	**99.5%**
	Total Basin Era	**433**	**369**	**64**	**5**	**85%**	**15%**	**98.5%**
	Total HDR Era	**65**	**55**	**10**	**0**	**85%**	**15%**	**100%**
	Total	**885**	**738**	**147**	**9**	**83%**	**17%**	**98.8%**
	24 Year Average	**37**	**31**	**6**	**0.37**	**84%**	**16%**	**98.8%**