MASSEY DRAW FLASH FLOOD - RAINFALL RECONSTITUTION

Prepared for:

Urban Drainage & Flood Control District
2480 West 26th Avenue, Suite 160B
Denver, Colorado 80211

Prepared by:

Henz Meteorological Services
1401 West Dry Creek Road
Littleton, Colorado 80120

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1.0 Introduction

On August 4, 1999 the Massey Draw basin in southeastern Jefferson County experienced a significant flash flood episode during the late afternoon and early evening hours. The event produced both stream and localized urban street flooding. The flash flooding was caused by the runoff from a two-hour period of heavy thunderstorm rainfall followed by an additional five to seven hours of steady rainfall with brief periods of moderate thundershowers.

The Massey Draw basin is located in southeastern Jefferson County just to the north of Chatfield Reservoir and approximately 12 miles south-southwest of downtown Denver. The basin is shown in Figure 1 on a map provided by Urban Drainage & Flood Control District.

This brief technical report presents the highlights of the rainfall reconstruction requested by Urban Drainage & Flood Control District.

2.0 Rainfall Reconstitution

HMS has developed a standard technique for accomplishing radar-rainfall reconstitutions for the Urban Drainage & Flood Control District. This technique has been described in several publications, which are referenced at the conclusion of the report.

In general, HMS utilizes the standard Level III base reflectivity observations taken by the National Weather Service (NWS) at their WSR-88D located near Watkins, Colorado. This radar is within 40 miles of the entire basin and thus provides a clear radar picture of the storm. The observations used were taken at a 0.5-degree elevation angle, which is a standard observation mode.

HMS acquires the base reflectivity data through a satellite data feed from Kavouras, Inc a NIDS provider. Kavouras provides the data in an x-y co-ordinate system instead of the standard NWS polar coordinate format. The Kavouras format simplifies navigating the data into a MapInfo Pro GIS format, which HMS links to Microsoft Excel 7.0 spreadsheets.

HMS has created a workbook comprised of sheets of both radar reflectivity level data and radar-estimated rainfall. Maps of the basin have been superimposed over the spreadsheets and presented in a 0.5 by 0.5 mile square. This size grid approximates very closely the scale of each pixel of the NWS radar reflectivity observations.

A basin grid is prepared for each of the WSR-88D observations times and it is placed in a spreadsheet. A workbook of observation spreadsheets is prepared for each storm and summations of rainfall prepared from these estimations.

HMS follows a five-step process in assigning a rainfall value to each radar reflectivity value:

1. First, the radar data is navigated into the MapInfo Pro grid. The grid consists of 0.5 by 0.5 mile squares. The entire basin is then identified on the grids using boundaries supplied by the District.

2. Next, HMS calculates the atmospheric peak hourly rainfall rates using observations from the District Mesonet weather stations, the NWS atmospheric sounding and the equations below once an hour:

$$\textbf{Peak 60-minute rainfall} = \textbf{PWI* times } \frac{\textbf{(Depth of updraft warm layer)}}{\textbf{1.5km}} \textbf{ times 2**}$$

Peak 30-minute rainfall = 0.70 (Peak 60-min rain)
Peak 10-minute rainfall = 0.60 (Peak 30-min rain)

3. Next, these equations are used to atmosphere truth the peak radar reflectivity levels and rainfall rates observed in the 55 dBZ or greater portions of the storm. Lower reflectivity levels and rainfall rates are logarithmically assigned as seen in the table below:

Radar Z - Level	Peak 60-min 4.80"	Peak 30-min 3.43"	Peak 10-min
2	0.10"/5min	0.22"/5min	
3	0.20"/5min	0.30"/5min	
4	0.30"/5min	0.41"/5min	
5	0.40"/5min	0.57"/5min	
6	0.40"/5min	0.57"/5min	

4. Next, HMS takes the radar-estimated rainfall and compares it to observed District gauges. This step allows the data to be ground-truthed with actual gauge data and radar data within the atmospheric structure observed. Additionally, HMS ground-truths the radar reflectivity data to see if rainfall is actually observed when the radar would estimate rain are occurring. Frequently HMS is able to detect non-raining updraft areas of the storm using this technique. This knowledge is used to interpret the radar data and assign rain rates.

This process insures reasonable radar-rainfall estimation and accounts for most of the errors commonly observed in such calculations.

3.0 Observed Rainfall Characteristics

The user of this rainfall data will find the data in standard Excel 7.0 workbook formats on the attached 3.5-inch diskette. Rainfall observations are provided for each radar observation with a standard observation interval of about 6 minutes, the time it takes the radar dish to rotate about its axis one time.

HMS has prepared four tables of information on this storm exclusive from this workbook. Each table is a colorized map of rainfall or radar reflectivity for the event.

Table 1 shows the thunderstorm rainfall, which fell across Massey Draw from 430PM until 630PM. During this period three distinct thunderstorms crossed a portion of the basin producing the approximately four square mile area of rainfall over 4.00 inches. The peak rainfall amount in this period was 5.21 inches in the north-central portion of the basin. It is interesting to note the over 3:1 increase in rainfall from the western to central portions of the basin in a short distance of less than 3 miles. A time distribution of the rainfall in the grid square receiving the most rainfall is also presented. It shows the passage of the three storm cells and the dominating influence of the final cell, which persisted for almost an hour.

Table 2 shows the rainfall from 630PM until 1159PM, MDT that fell as a more general steady rain with a few brief periods of thunder rain showers. Note that the eastern end of the basin received 2-4 times as much rainfall as the western third of the basin. The stratiform rainfall peaked at 2.87 inches in one grid and its time distribution is shown.

Finally, Table 3 shows the storm total rainfall for the summed thunderstorm and strati-form rainfalls. Note that the central portion of the basin received 5.50" to over 7.00 inches of total rain. The peak grid rain of 7.46 inches fell close to the unofficial reports of almost 6 inches of rain received from a cooperative local observer.

Finally, Table 4 shows the summed WSR-88D radar reflectivity levels for the storm. Clearly the radar summation locates the location of the peak rainfall but seems to miss the aerial distribution of the rainfall shown in Table 3. This result puts a caution to using NWS radar precipitation products for flash flood prediction.

4.0 Conclusion

A radar estimated rainfall study was completed for the Massey Draw flash flood of August 4, 1999. Basin average rainfall of almost 4.00 inches was noted with a peak point rainfall of 7.46 inches due to a combination of two hours of thunderstorm rain and seven hours of general rainfall.

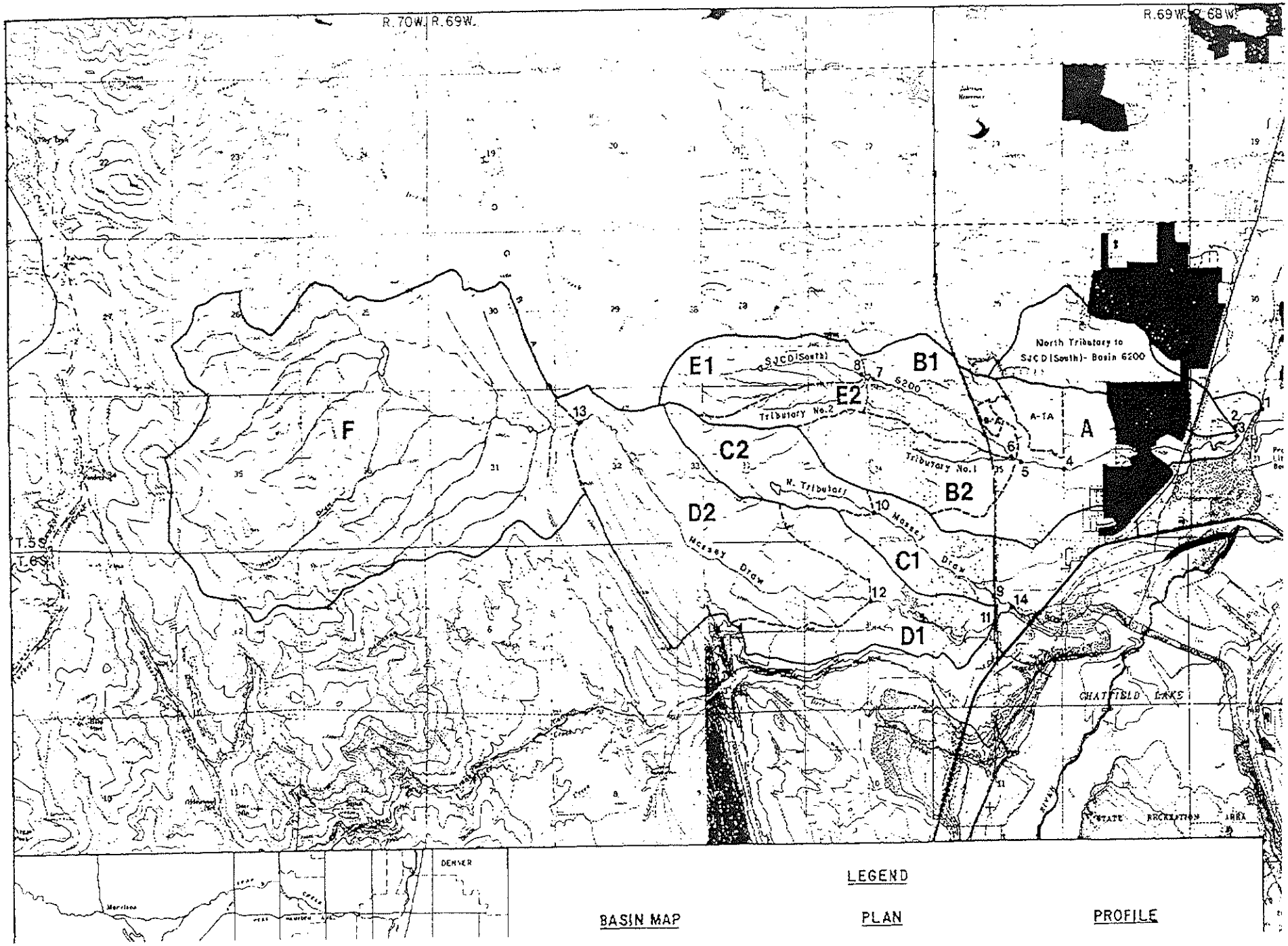
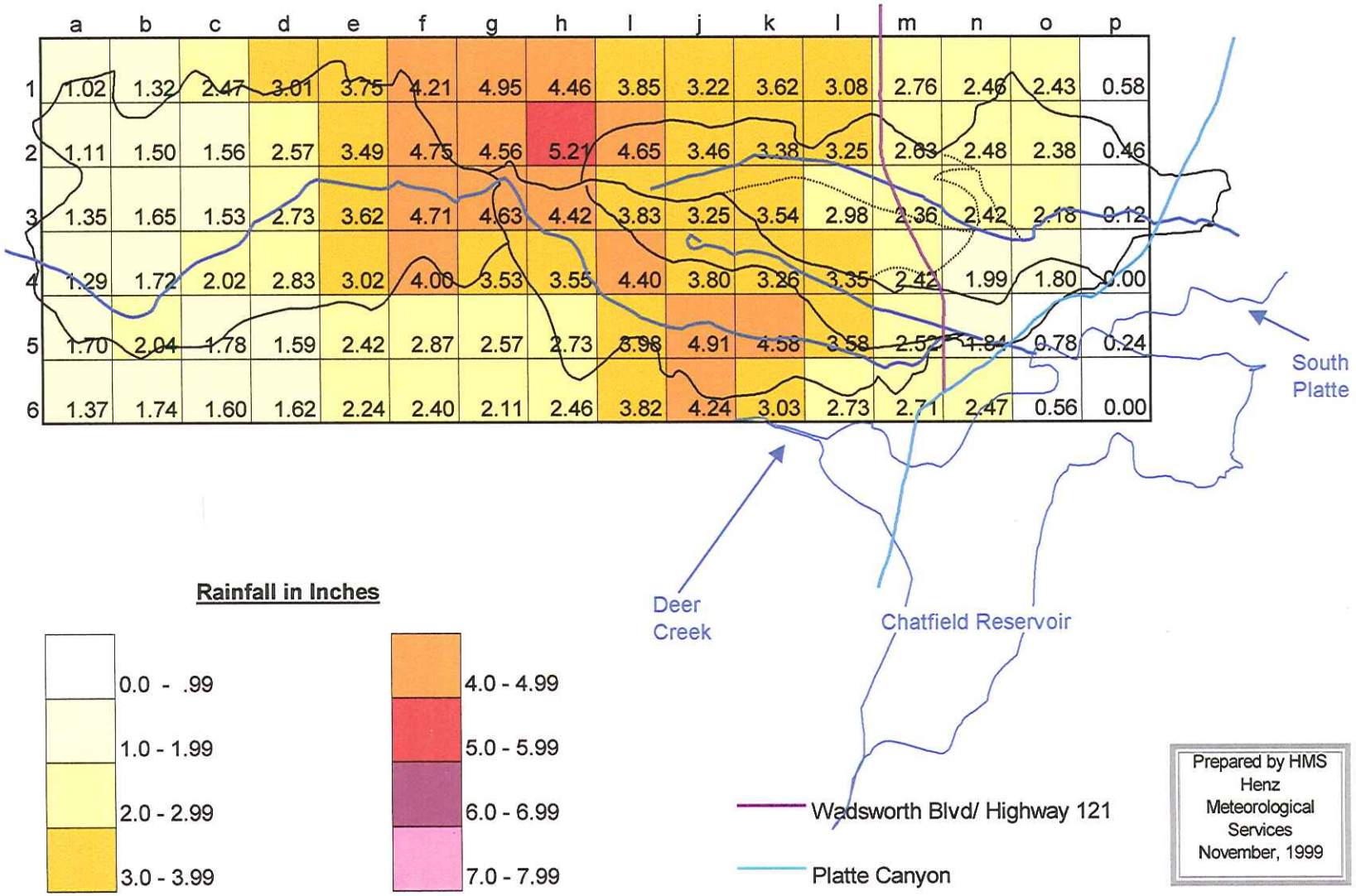

R.70W.
R.69W.
R.69W.
R.68W.
E1
E2
B1
B2
C1
C2
D1
D2
F
A
A-1A
SJCD(South)
Tributary No.2
Tributary No.1
N. Tributary
Massey Draw
North Tributary to SJCD(South)- Basin 6200
CHATFIELD LAKES
STATE RECREATION AREA
T.5S.
T.6S.
DENVER
LEGEND
BASIN MAP
PLAN
PROFILE

Table 1. Thunderstorm Rainfall, 4:30 PM to 6:30 PM
Massey Draw, August 4, 1999

Each Grid Square Represents an Area of .5 mile by .5 mile

	a	b	c	d	e	f	g	h	I	j	k	l	m	n	o	p
1	1.02	1.32	2.47	3.01	3.75	4.21	4.95	4.46	3.85	3.22	3.62	3.08	2.76	2.46	2.43	0.58
2	1.11	1.50	1.56	2.57	3.49	4.75	4.56	5.21	4.65	3.46	3.38	3.25	2.63	2.48	2.38	0.46
3	1.35	1.65	1.53	2.73	3.62	4.71	4.63	4.42	3.83	3.25	3.54	2.98	2.36	2.42	2.18	0.12
4	1.29	1.72	2.02	2.83	3.02	4.00	3.53	3.55	4.40	3.80	3.26	3.35	2.42	1.99	1.80	0.00
5	1.70	2.04	1.78	1.59	2.42	2.87	2.57	2.73	3.98	4.91	4.58	3.58	2.52	1.84	0.78	0.24
6	1.37	1.74	1.60	1.62	2.24	2.40	2.11	2.46	3.82	4.24	3.03	2.73	2.71	2.47	0.56	0.00



From Table 1. Thunderstorm Rainfall
Single Grid Square with Highest, Total Amount of Rainfall (5.21 inches)
and Surrounding 8 Squares (35.35 inches)

X-Axis Ref No.	Green-wich Time	Mtn Std Time	Highest Square	Inches of Rain, G1	Inches of Rain, H1	Inches of Rain, I1	Inches of Rain, G2	Inches of Rain, I2	Inches of Rain, G3	Inches of Rain, H3	Inches of Rain, I3	Surrounding 8-Square Total	Surrounding 8-Square Avg
1	2221	421 PM	0.12	0.40	0.12	-	0.12	-	-	-	-	0.64	0.08
2	2227	427 PM	0.30	0.30	0.30	0.30	0.30	0.30	0.06	0.06	-	1.62	0.20
3	2239	439 PM	0.30	0.30	0.12	0.12	0.12	0.12	0.30	0.12	0.12	1.32	0.17
4	2245	445 PM	0.25	0.25	0.12	0.12	0.12	0.12	0.25	0.12	0.12	1.22	0.15
5	2251	451 PM	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.00	0.25
6	2257	457 PM	0.40	0.40	0.40	0.40	0.40	0.40	0.25	0.25	0.12	2.62	0.33
7	2303	503 PM	0.35	0.25	0.35	0.25	0.25	0.25	0.35	0.35	0.25	2.30	0.29
8	2309	509 PM	0.15	0.35	0.15	0.15	0.15	0.35	0.15	0.15	0.15	1.60	0.20
9	2315	515 PM	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.20	0.15
10	2321	521 PM	0.15	0.15	0.15	0.12	0.15	0.15	0.15	0.15	0.15	1.17	0.15
11	2327	527 PM	0.35	0.35	0.35	0.15	0.35	0.15	0.35	0.35	0.35	2.40	0.30
12	2333	533 PM	0.35	0.15	0.15	0.15	0.15	0.35	0.12	0.35	0.35	1.77	0.22
13	2338	538 PM	0.35	0.15	0.15	0.12	0.35	0.35	0.35	0.35	0.35	2.17	0.27
14	2344	544 PM	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.15	2.60	0.33
15	2350	550 PM	0.25	0.15	0.25	0.25	0.25	0.25	0.15	0.25	0.15	1.70	0.21
16	2356	556 PM	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.00	0.25
17	2403	603 PM	0.25	0.15	0.25	0.15	0.25	0.25	0.25	0.25	0.25	1.80	0.23
18	2409	609 PM	0.25	0.15	0.15	0.15	0.15	0.25	0.15	0.25	0.25	1.50	0.19
19	2415	615 PM	0.15	0.15	0.15	0.12	0.15	0.12	0.25	0.15	0.15	1.24	0.16
20	2421	621 PM	0.12	0.15	0.15	0.15	0.15	0.12	0.35	0.15	0.12	1.34	0.17
21	2427	627 PM	0.12	0.15	0.15	0.15	0.15	0.12	0.15	0.12	0.15	1.14	0.14
			5.21	4.95	4.46	3.85	4.56	4.65	4.63	4.42	3.83	35.35	4.42

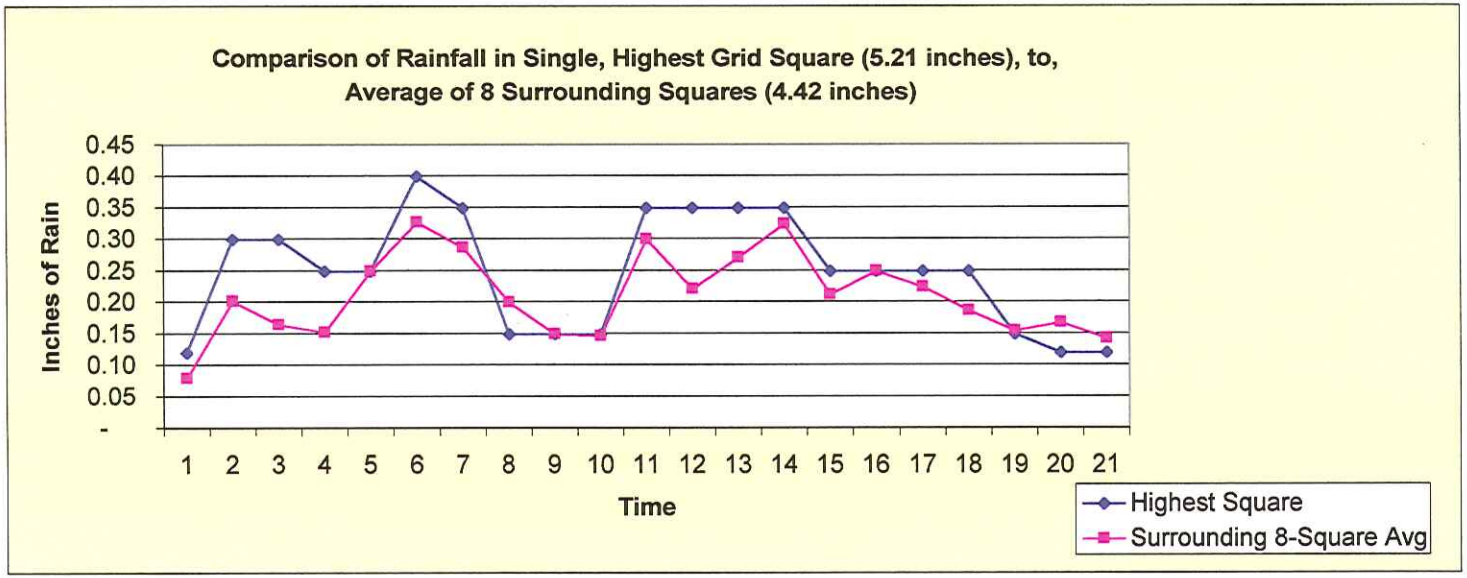


Table 2. Stratiform Rainfall, 6:30 PM to 11:59 PM
Massey Draw, August 4, 1999

Each Grid Square Represents an Area of .5 mile by .5 mile

	a	b	c	d	e	f	g	h	I	j	k	l	m	n	o	p
1	0.44	0.60	0.54	0.70	0.74	0.98	0.96	0.80	0.86	0.96	1.11	1.02	1.47	1.50	1.45	1.43
2	0.50	0.56	0.56	0.72	0.96	0.88	0.94	0.98	0.97	1.38	1.40	1.53	1.42	1.71	1.47	1.17
3	0.64	0.64	0.52	0.78	1.02	1.02	1.08	1.21	1.16	1.22	1.51	1.57	1.70	1.47	1.38	1.15
4	0.92	0.96	0.65	0.60	1.04	1.34	1.50	1.69	1.91	2.15	2.21	1.99	1.82	1.40	1.51	1.37
5	0.90	1.10	0.66	0.72	1.16	1.38	1.54	1.67	2.21	2.55	2.51	2.29	1.82	1.65	1.34	1.26
6	1.12	1.18	1.36	1.38	1.35	1.91	2.08	2.45	2.87	2.65	1.93	1.63	1.42	1.42	1.18	1.12

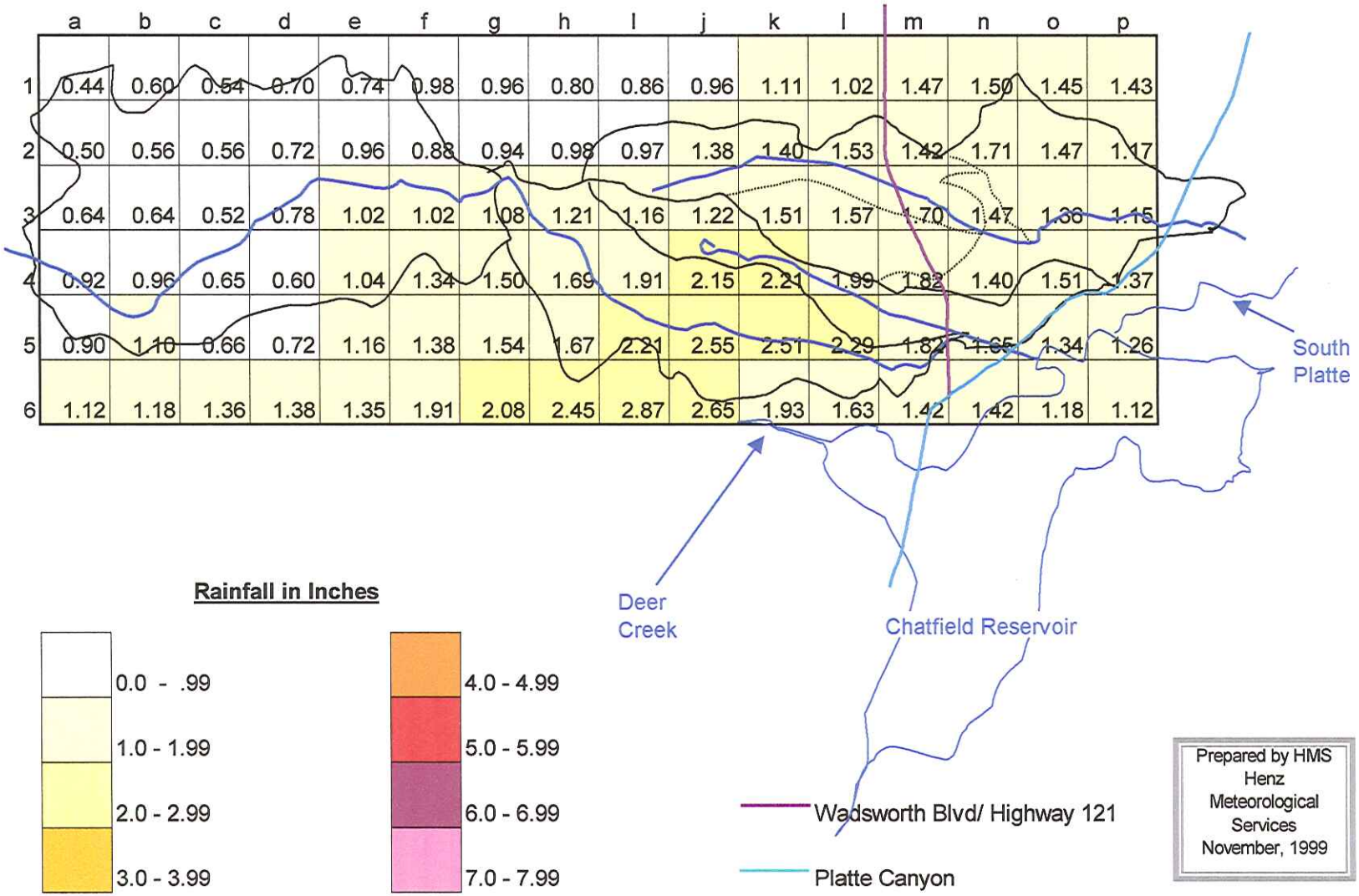


Table 3. Storm Total Rainfall
Massey Draw, August 4, 1999

Each Grid Square Represents an Area of .5 mile by .5 mile

	a	b	c	d	e	f	g	h	I	j	k	l	m	n	o	p
1	1.46	1.92	3.01	3.71	4.49	5.19	5.91	5.26	4.71	4.18	4.73	4.10	4.23	3.96	3.88	2.01
2	1.61	2.06	2.12	3.29	4.45	5.63	5.50	6.19	5.62	4.84	4.78	4.78	4.05	4.19	3.85	1.63
3	1.99	2.29	2.05	3.51	4.64	5.73	5.71	5.63	4.99	4.47	5.05	4.55	4.06	3.89	3.54	1.27
4	2.21	2.68	2.67	3.43	4.06	5.34	5.03	5.24	6.31	5.95	5.47	5.34	4.24	3.39	3.31	1.37
5	2.60	3.14	2.44	2.31	3.58	4.25	4.11	4.40	6.19	7.46	7.09	5.87	4.34	3.48	2.12	1.50
6	2.49	2.92	2.96	3.00	3.59	4.31	4.19	4.91	6.69	6.89	4.96	4.36	4.13	3.89	1.74	1.12

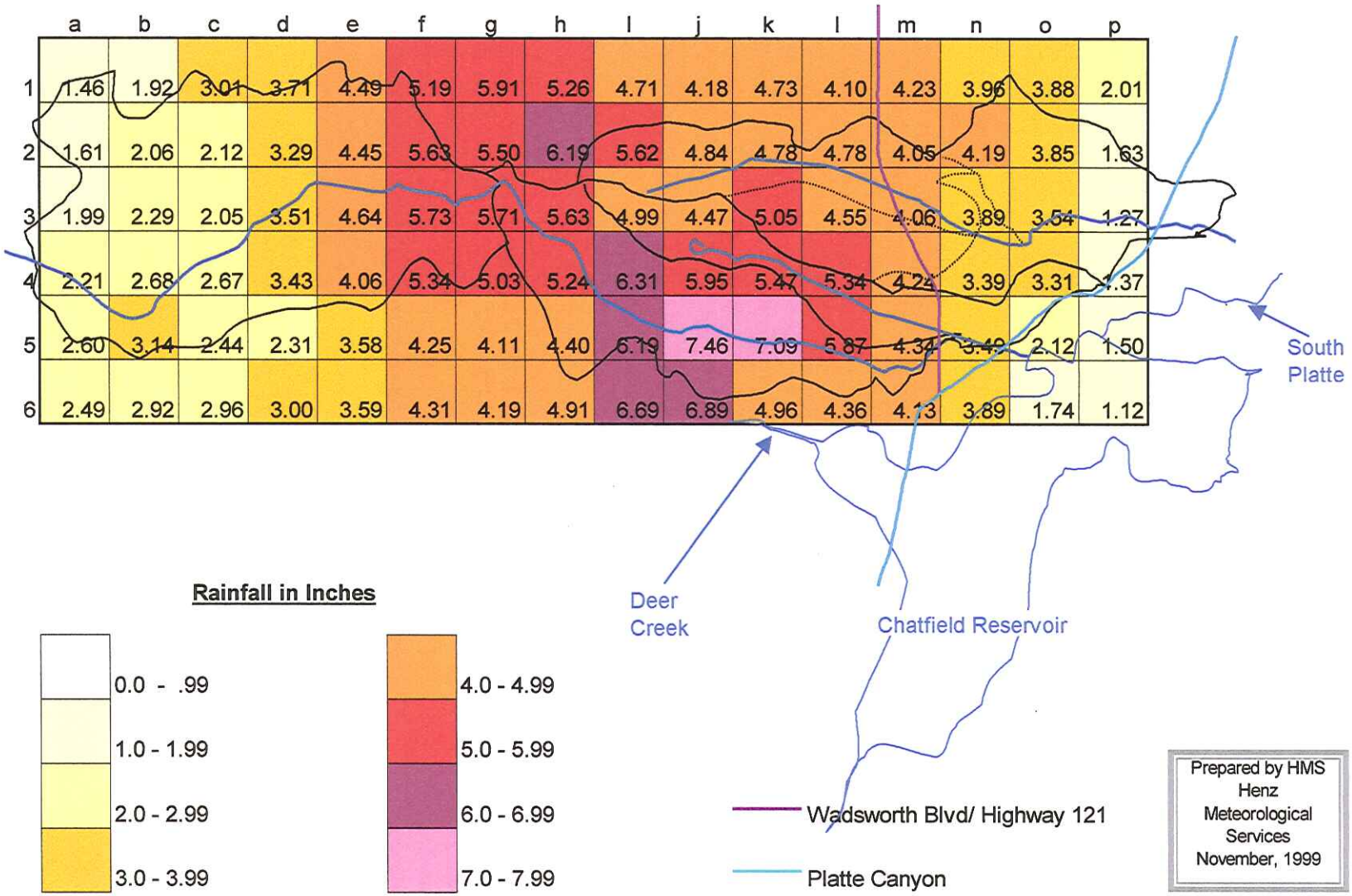


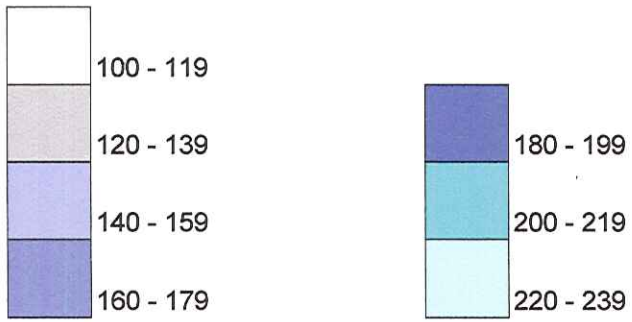
Table 4. Summed Incremental Radar Reflectivity Levels
Massey Draw, August 4, 1999, 4:30 PM to 11:59 PM

from WSR-880, NWS, Watkins, Colorado

Each Grid Square Represents an Area of .5 mile by .5 mile

105	126	144	163	176	188	197	189	181	181	183	178	180	176	174	127
113	132	132	150	176	192	196	199	191	190	188	189	177	180	172	125
128	138	132	156	182	197	199	200	194	191	192	183	184	180	169	116
141	155	146	150	170	199	204	206	210	208	210	206	191	174	169	118
145	158	136	137	168	186	193	197	217	225	222	210	194	180	142	122
148	155	164	167	174	191	195	203	218	217	199	193	189	181	123	108

Incremental Radar Reflectivity Values



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Henz
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Services
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