APPENDIX 3-G

Flood reconstitutions and worksheets, Denver.

284 pgs.

C)

Volume in drive A is DENVER#1
Directory of A:\

D1161	I3	415	10-21-87	8:04a
D1161	O3	20191	10-21-87	8:06a
DVI1	I1	321	9-10-87	4:38p
DVI1	O1	18081	9-10-87	4:39p
DVI1	I2	356	9-10-87	8:21p
DVI1	O2	18033	9-10-87	8:23p
DVI1	I3	381	10-21-87	11:08a
DVI1	O3	20803	10-21-87	11:10a
DVI1	I4	344	10-21-87	11:14a
DVI1	O4	19771	10-21-87	11:16a
DCD1	I2	412	10-21-87	12:57p
DCD1	O2	21529	10-21-87	12:58p
D1162	I1	470	9-10-87	3:23p
D1162	O1	20295	9-10-87	3:24p
D1162	O3	21163	10-21-87	10:47a
D1162	O2	20977	10-21-87	10:15a
D1162	I2	526	10-21-87	10:14a
D1162	I3	526	10-21-87	10:46a
D1162	I4	526	10-21-87	10:51a
D1162	O4	20927	10-21-87	10:53a
DSC1	I4	387	10-21-87	1:56p
DSC1	O4	21512	10-21-87	1:58p
DSC2	I2	446	10-21-87	2:14p
DSC2	O2	21799	10-21-87	2:16p
DGC1	I3	571	10-21-87	1:25p
DGC1	O3	21872	10-21-87	1:27p

26 File(s) 74752 bytes free

Station	Table No.	Storm Date	Rainfall Depth inches	Rainfall Max Intensity in/hr	Rainfall Duration hr-min	Runoff Peak Discharge cfs	Runoff Depth inches	
(1)		(2)	(3)	(4)	(5)	(6)	(7)	
		Denver Metropolitan Area						
DBDC								
Big Dry Creek tributary	48	3 May 81	.40	3.2	0-25	16.	.12	82-872
	54	11-12 Jun 81	.51	3.4	0-35	26.	.35	82-872
	56	17 Jul 81	.58	3.6	0-55	25.	.19	82-872
DAP								
Asbury Park	20	14 Aug 80	.47	3.0	1-0	23.	.10	81-682
	22	14-15 Aug 80	.48	3.0	1-15	44.	.14	81-682
DNA								
North Avenue Storm Drain	36	14-15 Aug 80	.76	3.6	0-55	16.	.16	81-682
	91	26-27 Jul 81	.89	3.6	1-40	21.	.11	82-872
DCK								
Cherry Knolls Storm Drain	111	3 May 81	.37	2.2	0-45	13.	.09	82-872
	116	28 May 81	.18	3.2	0-15	9.8	.03	82-872
D116								
116th Ave & Claude Ct.	44	9 May 80	.22	2.8	0-25	10.	.02	81-682
	126	3 May 81	.27	2.8	0-25	29.	.07	82-872
	130	3 Jun 81 ✓	.93	4.4	0-35	123.	.37	82-872
	136	22 Aug 81 ✓	.32	2.8	0-35	28.	.05	82-872
DVI								
Villa Italia Storm Drain	141	20 Apr 81 ✓	.54	2.8	0-40	77.	.43	82-872
DCD								
Concourse D Storm Drain		25 Jul 71 ✓	.80	5.3	0-20	115.	.42	#27, 51
		1 Aug 76 ✓	2.08	4.3	1-35	285.	1.78	79-126, 158
DBC								
Boulder Creek tributary at Boulder		23 Jul 71	.96	3.1	1-0	24.	.16	#27, 35
		16 Jun 72 ✓	2.25	6.7	1-15	123.	.73	#38, 340
		23 Jun 76 ✓	1.14	3.2	0-50	80.	.36	79-126, 393
DTG								
Toll Gate Creek tributary at Aurora		25 Jul 71	1.09	16.0	0-30	145.	.24	#27, 144
DWC								
Westerly Creek Tributary at Aurora		25 Jul 71	.65	6.0	0-25	61.	.45	#27, 187
DDG								
Dry Gulch tributary at Lakewood		12 Jun 73 ✓	3.41	1.5	0-45	224.	.41	#38, 79
		29 Jul 73 ✓	.65	4.1	0-30	134.	.14	#38, 82
DSP								
South Platte tributary at Denver		19 Jul 73 ✓	1.17	5.5	0-35	105.	.39	#38, 95
DGC								
Goose Creek at Boulder		25 Jul 76 ✓	.99	4.7	1-45	137.	.30	79-126, 361
DSC								
Sand Creek tributary at Denver		7 Aug 73 ✓	1.94	5.6	0-55	236.	.67	#38, 165
		30 Jul 74 ✓	1.38	4.0	0-45	251.	.50	#38, 172
		1 Aug 76 ✓	1.3	4.2	1-5	196.	.40	79-126, 177

Selection of Denver events for data entry, tabulating, & plotting

station (1)	Date (2)	Start Time (3)	End Time (4)	# of raingages (5)	Report (6)	Pg / Table (7)	File Name (8)	
116 th Ave & Claude Ct.	3 Jun 81	1435	1650	1	82-872	195 /130	D1	D1161
	22 Aug 81	1330	1445	3	82-872	201 /136	D2	D1162
Villa Italia Storm Drain	20 Apr 81	1250	1415	1	82-872	207 /141	D3	DVI1
Concourse D Storm Drain	~~25 Jul 71~~	~~1905~~			~~#27~~	~~51~~	~~D4~~	
	1 Aug 76	1510	1735	1	79-1261	158, 159	D4	DCD1
Boulder Ck. trib. @ Boulder	~~23 Jul 71~~	~~1815~~			~~#27~~	~~35~~	~~D~~	
	16 Jun 72	1830	2055	1	#38	340	D5	DBC1
	23 Jun 76	1305	1705	1	79-1261	393, 394	D6	DBC2
~~Toll Gate Ck. trib. @ Aur.~~	~~25 Jul 71~~				~~#27~~	~~144~~		
~~Westerly Ck. trib. @ Aur.~~	~~25 Jul 71~~				~~#27~~	~~187~~		
Dry Gulch trib. @ L-wood	12 Jun 73	1605	1755	1	#38	79, 80	D7	DDG1
	29 Jul 73	1435	1535	1	#38	82	D8	DDG2
S. Platte trib. @ Denver	19 Jul 73	2035	2340	1	#38	95, 96	D9	DSP1
Goose Ck. @ Boulder	25 Jul 76	~~1555~~	2250	1	79-1261	361, 362	D10	DGC1
Sand Ck. trib. @ Denver	7 Aug 73	1615	1805	1	#38	165, 166	D11	DSC1
	30 Jul 74	0540	0715	1	#38	172, 173	D12	DSC2
	1 Aug 76	1800	2035	1	79-1261	177	D13	DSC3

16 Jan 87

D116 116th Ave & Claude Ct. 06720420

1. aerial photo & drainage map, Plate 6, 81-682
2. watershed description, pg. 7, 81-682
3. Basin chara. table (copy)
4. subcatchment data, pg. 140, 81-682
5. maps, pgs. 87-90, USGS Draft report

DVI Villa Italia Storm Drain 394236105042400

1. aerial photo & drainage map, Plate 7, 81-682
2. watershed description, pg. 7, 81-682
3. Basin chara. table (copy)
4. subcatchment data, pg. 141, 81, 682
5. maps, pgs 91-94, USGS Draft Report

DCD Concourse D storm Drain 06714300

1. station description, pg. 145, 79-1261

DBC Boulder Ck. trib. @ Boulder 06728400

1. station description, pg. 388, 79-1261

DGC Goose Ck. @ Boulder 06728350

1. station description, pg. 345, 79-1261

DSC Sand Creek trib. 06714310

1. station description, pg. 169, 79-1261

DSP S. Platte R. trib. 06714210

1. station description, pg. 102, 79-1261

DDG Dry Gulch @ Lakewood 06711700

1. station description, pg. 72, #38

9 Sept. 87

Phone call to Sherm Ellis, USGS,

Requested information on USGS watersheds that were ~~used~~ monitored prior to the NURP.
They do not have any better watershed maps or data other than what has been published.
This older data was collected for Urban Drainage.
Ben Urbonas may have maps.

Summary of data for 1980 open-file report 81-682

Table No.	Station	Date	Rainfall	Intensity	Peak Q
12	Big Dry Ck @ Easter	15-16 May	.74	.4	4.1
13		17 May	.39	.4	2.3
14		1 July	.28	.4	4.0
15	Rooney Gulch	23-24 April	2.82	0 ?	2.4
16		30 April – 2 May	1.98	2.2	11
17		8-9 May	.25	1.0	2.2
18		15-16 May	.77	1.6	4.5
19		16-18 May	.61	.8	4.5
20	Asbury Park	14 Aug.	.49	3.0	23.
21		1-2 July	.34	.4	6.2
22		14-15 Aug	.59	3.0	44
23		20 Sept.	.21	2.0	15
24	North Ave @ DFC	8 May	.37	.4	2.8
25		11 May	.09	.2	2.1
26		12 May	.03	.2	1.7
27		15-16 May	.53	.4	3.8
28		17 May	.29	.2	2.6
29		24 July	.13	.6	2.8
30		10 Aug	.05	.2	.7
31		8-9 Sept	.75	.6	5.1
32		10 Sept	.23	.2	.99
33		10 Sept	.23	1.4	7.0
34		20 Sept	.21	.8	4.8
35		24 July	.13	1.0	1.7
36		14-15 Aug	1.14	3.6	16. ←
37		8 Sept	.19	.2	.53
38		8-9 Sept	.75	—	2.5
39		10 Sept	.23	.2	.63
40		10-11 Sept	.26	1.8	7.5
41	Cherry Knolls	14 Aug		2.8	17
42	116th Ave & Claude Ct.	7-8 May		.8	17
43		8 May		.2	3.2
44		9 May		2.8	10. ←
45		11 May		.2	1.3
46		1-2 July		.4	5.0

47	116th Ave & Claude Ct.	2 July	2.4	30.
48		15 Aug	1.0	7.0
49		25-26 Aug	.6	5.4
50		26-27 Aug	1.6	16.
51		20 Sept.	1.4	11.
52	Villa Italia	1-2 July	.6	21.
53		11 July	.4	4.8
54		30 July	.4	5.8
55		7 Aug	1.0	13
56		10 Aug	.2	4.9
57		14-15 Aug	7.4	46
58		25 Aug	.8	23
59		8 Sept.	.4	4.5
60		8-9 Sept.	.4	7.7
61		10 Sept.	.2	5.0
62		10 Sept.	1.2	19.
63		20 Sept.	1.0	33.

USGS Basic-Data Release No. 27
Data for June 1968 – September 1971

Date	Rainfall	Intensity	Peak Q	Page
Boulder Creek trib. @ Boulder, CO				.2 mi²
✓ 23 July 71	.96	3.12	24	35
Concourse D storm Drain				.11 mi²
✓ 25 July 71	.80	5.28	115	51
Toll Gate Creek trib. at Aurora				.3 mi²
✓ 25 July 71	1.09	6.00	145	144
Westerly Creek trib @ Aurora				.2 mi²
✓ 25 July 71	.65	6.00	61	187

Basic-Data Release No. 38
Data for October 1971 through September 1974

South Platte trib. @ Englewood				1.06 mi²
X 3 Aug. 72	1.14	3.36	154	20-21
Lakewood Gulch trib. @ Lakewood				.3 mi²
✓ 12 June 73	3.41	1.52	224	79-80
✓ 29 July 73	.67	4.08	134	82
South Platte trib. @ Denver				.5 mi²
✓ 19 July 73	1.17	5.52	105	95-96
Sand Creek trib. @ Denver				.3 mi²
✓ 7 Aug 73	1.95	5.64	236	165-166
✓ 30 July 74	1.39	3.96	251	172-173
Boulder Creek trib. @ Boulder				.08 mi²
✓ 16 June 72	2.25	6.72	123	340

Open-File Report 79-1261
Data for October 1974 through September 1977

Concourse D storm drain				.15 mi²
✓ 1 Aug 76	2.08	4.32	285	158-159
Sand Creek trib. @ Denver				
✓ 1 Aug. 76	1.30	4.20	196	177
Goose Creek @ Boulder				.69 mi²
✓ 25 July 76	.99	4.68	137	361-362
Boulder Creek trib. @ Boulder				.20 mi²
✓ 23 June 76	1.14	3.24	80	393-394

Mike Senseke 10 Sept. 87

Harvard Gulch	Qp H.P.	Qp Colo. Blvd.	rain intensity, 5 min Beth	Brad	Slav	H.P.	N.
18 July, 1985	88	203	.17	.29	.11	.02	.06
1615-2005 19 July, 1985	720	392	.51	.33	.20	.74	1.06
320-0230 19-20 July, 1985	425	350	.23	.28	.35	.13	.22
5 Aug 1983	519	410	.28	.34	.31	.06	.40
28 May 1981	672	395	?				

Sand Creek				
14 June 1982	240 cfs	?	?	duration
21 July 1983	191 cfs	.13	.18	4 hr
29 June 1984	213 cfs	.03	.19	20 min
2 June 1985	322 cfs	.09	.19	45 min
19 June 1985	344	.26	.22	4 hr
2 Aug 1982	123	.23	.30	40 min

Sanderson Gulch				
4 July 1979	113 cfs	.27		1 hr
12 June 1983	125	.15	.23	50 min
14 July 1985	133			30 min
30 July 1985	143			15 min

Flood Reconstitution for Denver 116th Ave. & Claude Ct. D1161

Storm Event 3 June 81

Runoff: depth = .36 inches, Q_p = 123 cfs at t_p = .50 hours

$R_{recession}$ = .18 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
170.0	24	.93	5	D		125	.58	.10	.21	.22	.19	Ø1	eff. imp. area too large
"	13.3	"	2	"		132	.50	.03	.27	.62	.19	Ø2	
"	"	"	"	u-1		131	.50	.08	.27	.61	.23	Ø3	← best

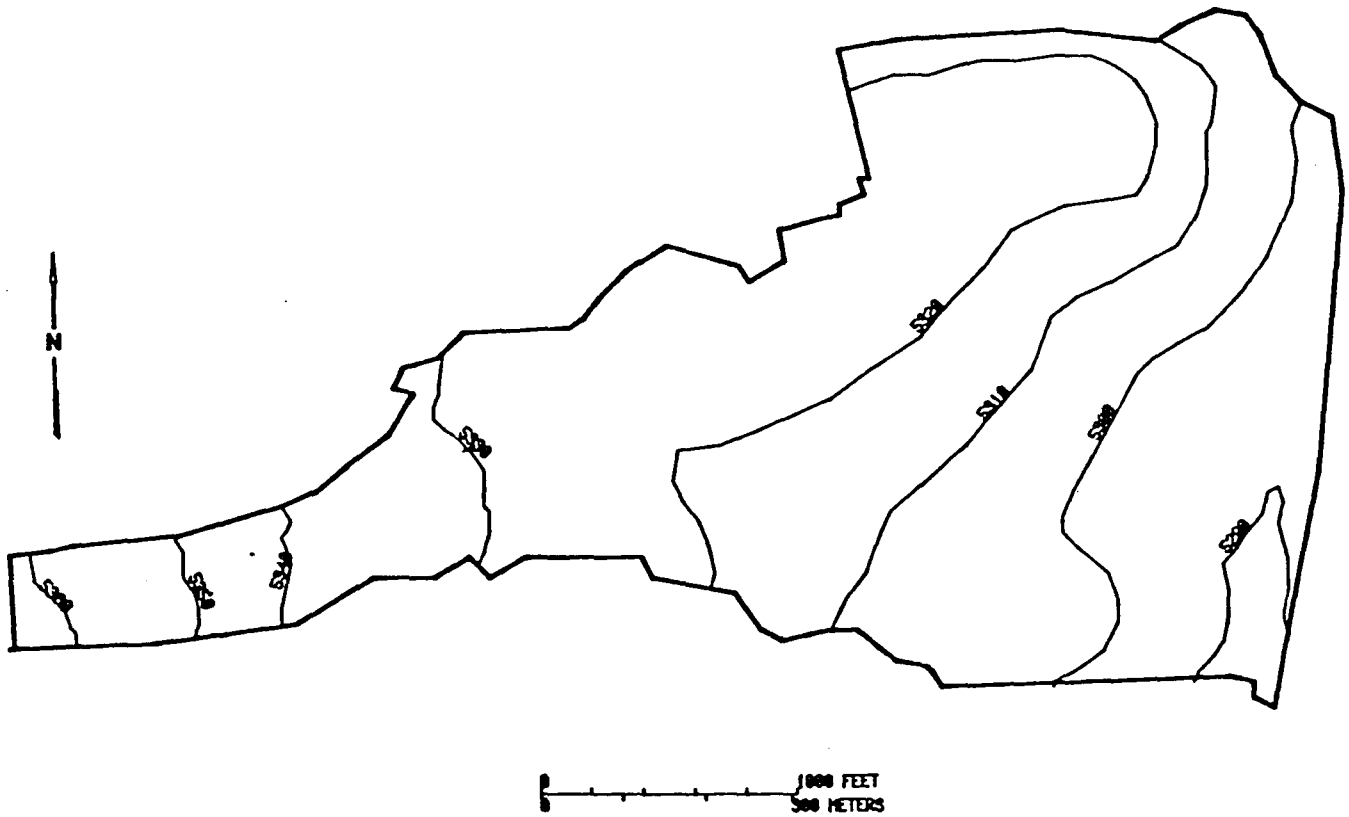
Flood Reconstitution for Denver 116 Ave & Claude Ct. D1162

Storm Event 22 Aug 81

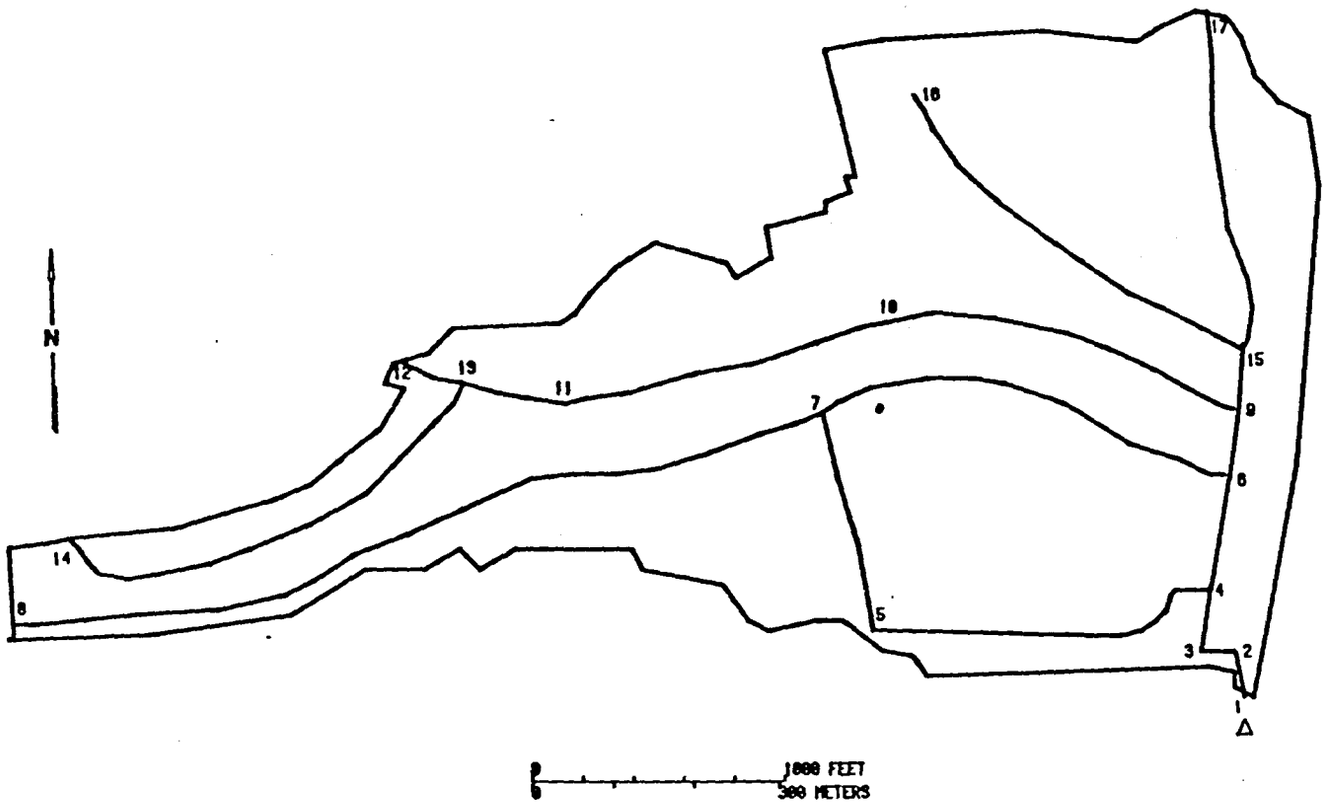
Runoff: depth = .05 inches, Q_p = 28 cfs at t_p = .27 hours

$R_{recession}$ = .27 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
170.0	24	.33	5	D		26	.33	.09	.24	.61	.12	Ø1	
"	13.3	"	2	U-1		20	.30	.20	.11	.40	.08	Ø2	This event cannot be satisfactorily reconstituted.
"	"	"	"	"	changed rain dist.	22	.30	.33	.10	.40	.08	Ø3	
"	"	"	"	"	"	20	.30	.22	.08	.40	.08	Ø4	



Denver, Colorado 06720420 - Storm Drain at One-hundred and Sixteenth Avenue and Claude Court at Northglenn, Colorado	Topography Map

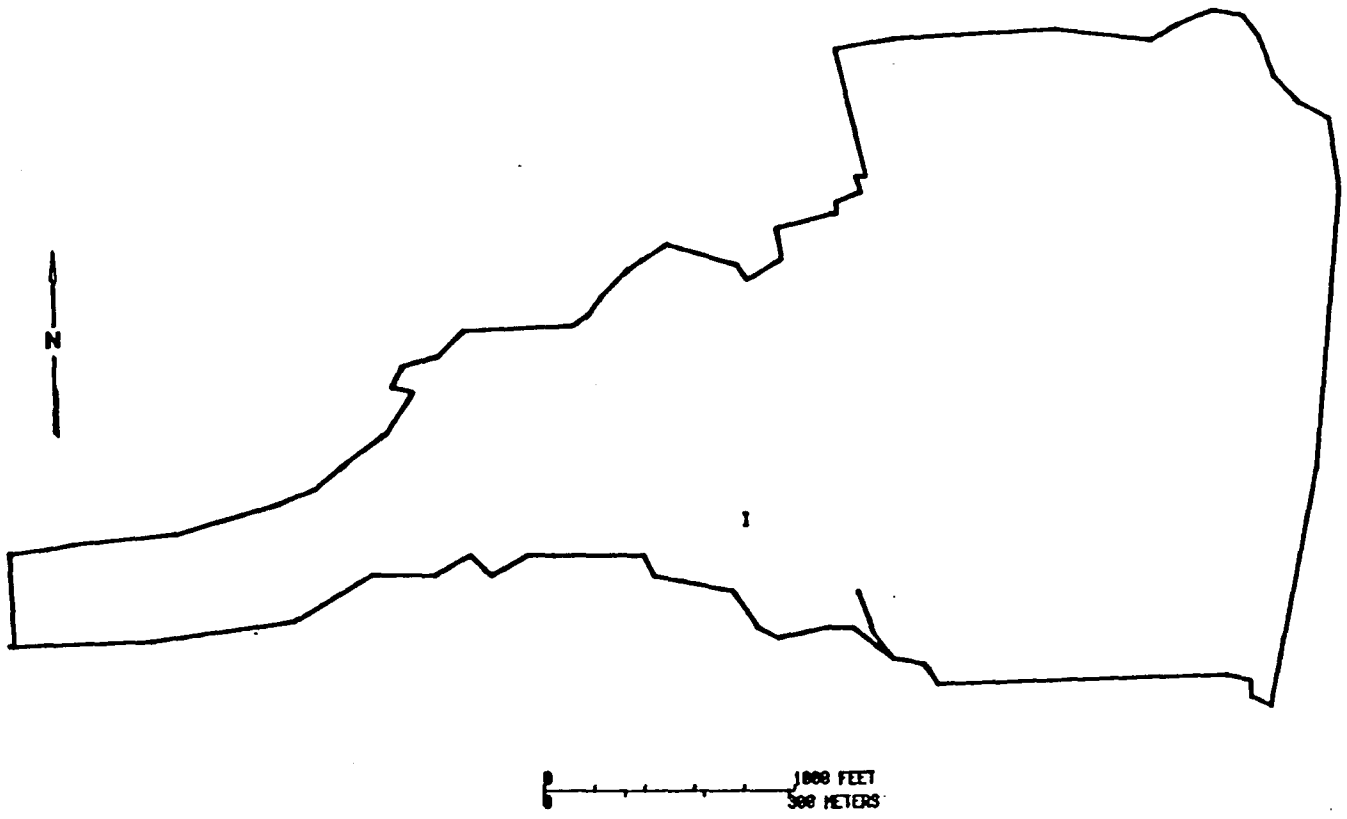


8.1"

Denver, Colorado 06720420 - Storm Drain at One-hundred and Sixteenth Avenue and Claude Court at Northglenn, Colorado	Drainage Map Tot. Drainage Area - 0.26

PIPE DATA FOR SITE : 06720420

Key Nos.		Shape	Dimension (inches)	Slope (ft/ft)	Length (feet)	Material
2	3	Circular	48	0.024	180	?
3	4	Circular	48	0.024	400	?
4	5	Circular	?	0.014	1500	?
5	7	Circular	?	0.009	780	?
4	6	Circular	48	0.024	260	?
6	7	Circular	?	0.013	2520	?
7	8	Circular	?	0.019	2625	?
6	9	Circular	48	0.024	260	?
9	10	Circular	36	0.019	1470	?
10	11	Circular	30	0.005	1100	?
11	12	Circular	?	0.014	1000	?
13	14	Circular	?	0.019	1800	?
9	15	Circular	24	0.018	260	?
15	16	Circular	?	0.015	1920	?
15	17	Circular	?	0.009	1420	?



	Land Use Map
Denver, Colorado 06720420 - Storm Drain at One-hundred and Sixteenth Avenue and Claude Court at Northglenn, Colorado	Impervious Area - 37.00 Population Density - 5900000

Table 81.--Subcatchment data for Storm Drain at 116th Avenue and Claude Court, at Northglenn, for use with U.S. Geological Survey's Distributed Routing Rainfall-Runoff Model, Version II

Sub-catchment number	Drainage area (acres)	Gutter or pipe for drainage	Overland flow length (ft)	Percent effective impervious area	Slope (ft/ft)	Manning *n* value	Thiessen coefficient		
							Rain gage 1	Rain gage 2	Rain gage 3
1	11.5	21	278	21	0.026	0.016	0	1.0	0
2	13.6	22	226	22	.019	.016	0	1.0	0
3	10.7	23	466	24	.016	.016	0	.97	0
4	11.7	24	463	21	.018	.016	0	.73	.27
5	28.7	25	496	34	.016	.016	.20	.80	0
6	6.3	26	350	13	.011	.016	0	1.0	0
7	23.7	27	727	21	.018	.016	.21	0	.79
8	24.9	28	565	24	.025	.016	.27	0	.73
9	16.2	29	480	24	.022	.016	.31	.28	.41
10	15.5	30	450	22	.018	.016	.58	.42	0
11	4.6	31	290	14	.018	.016	1.0	0	0

Table 82.--Gutter and pipe data for Storm Drain at 116th Avenue and Claude Court, at Northglenn, for use with U.S. Geological Survey's Distributed Routing Rainfall-Runoff Model, Version II

Gutter or pipe number	Gutter or pipe for drainage	Length (ft)	Slope (ft/ft)	Type[1]	Left side slope (ft/ft)	Right side slope (ft/ft)	Diameter (ft)	Manning *n* value
21	23	1,800	0.019	G	50	---	---	0.013
22	25	2,625	.019	G	50	---	---	.013
23	24	1,000	.014	G	50	---	---	.013
24	29	1,100	.005	C	-----	---	2.5	.016
25	34	2,520	.013	G	50	---	---	.013
26	30	780	.009	G	40	---	---	.013
27	32	1,420	.009	G	33	---	---	.013
28	32	1,920	.015	G	33	---	---	.013
29	33	1,470	.019	C	-----	---	3.0	.016
30	35	1,500	.014	G	25	---	---	.013
31	37	695	.006	G	33	---	---	.013
32	33	260	.018	C	-----	---	2.0	.016
33	34	260	.024	C	-----	---	4.0	.016
34	35	260	.024	C	-----	---	4.0	.016
35	36	400	.024	C	-----	---	4.0	.016
36	38	180	.024	C	-----	---	4.0	.016
37	38	460	.012	V	1.75	2.3	---	.04

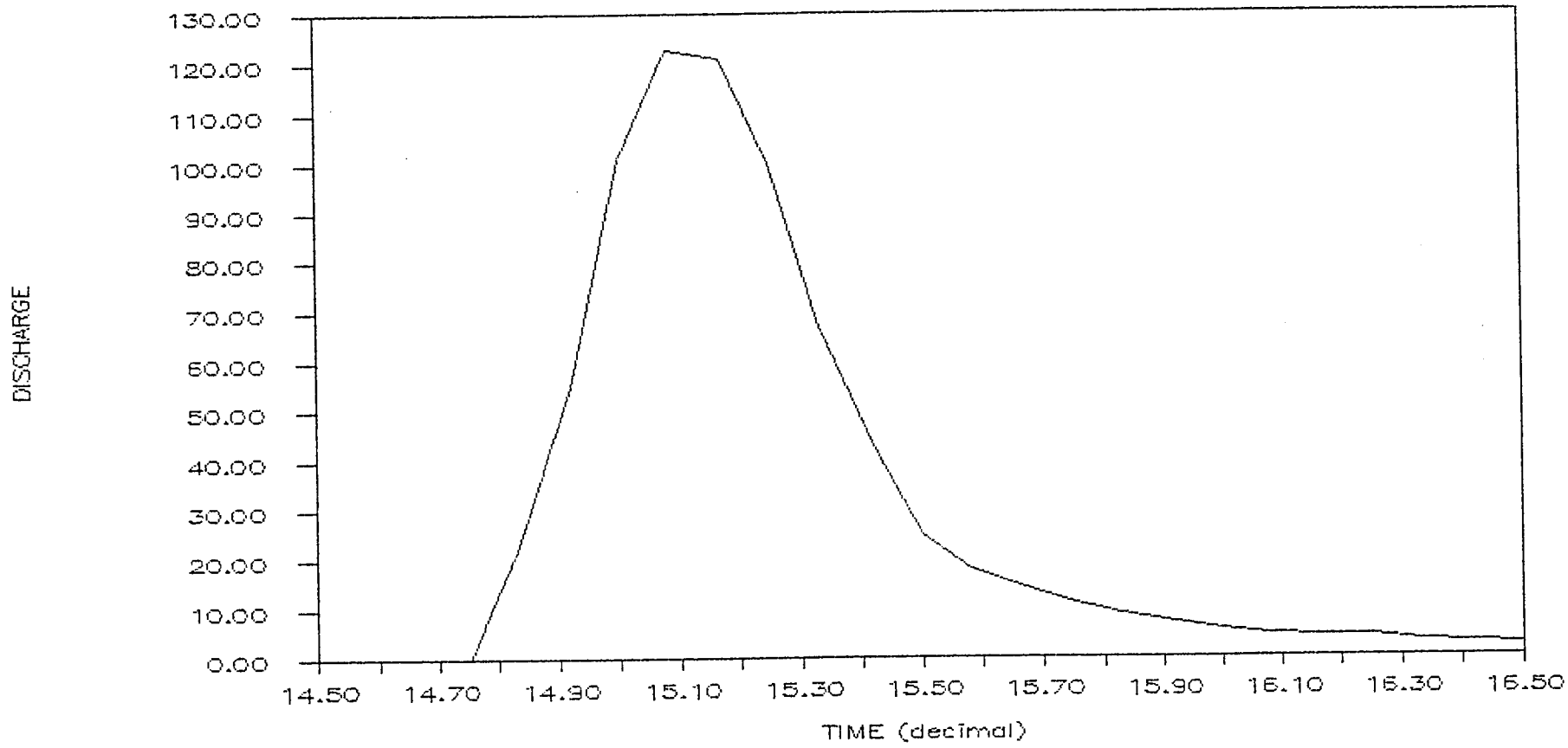
[1]V=V-shaped; C=Circular pipe; G=Gutter.

DENVER DATA	DATE	TIME	Q	P1	sum P1
116th Ave and Claude Ct.	03-Jun-81	1435	0.00	0.00	0.00
		1440	0.00	0.04	0.04
		1445	0.00	0.17	0.21
		1450	22.00	0.15	0.36
		1455	55.00	0.22	0.58
		1500	101.00	0.21	0.79
		1505	123.00	0.10	0.89
		1510	121.00	0.04	0.93
		1515	100.00	0.00	0.93
		1520	67.00	0.00	0.93
		1525	42.00	0.00	0.93
		1530	25.00	0.00	0.93
		1535	18.00	0.00	0.93
		1540	14.00	0.00	0.93
		1545	11.00	0.00	0.93
		1550	8.90	0.00	0.93
		1555	7.10	0.00	0.93
		1600	5.80	0.00	0.93
		1605	4.70	0.00	0.93
		1610	4.40	0.00	0.93
		1615	4.10	0.00	0.93
		1620	3.30	0.00	0.93
		1625	2.90	0.00	0.93
		1630	2.40	0.00	0.93
		1635	2.00	0.00	0.93
		1640	1.60	0.00	0.93
		1645	1.30	0.00	0.93
		1650	1.10	0.00	0.93

1655 1.0

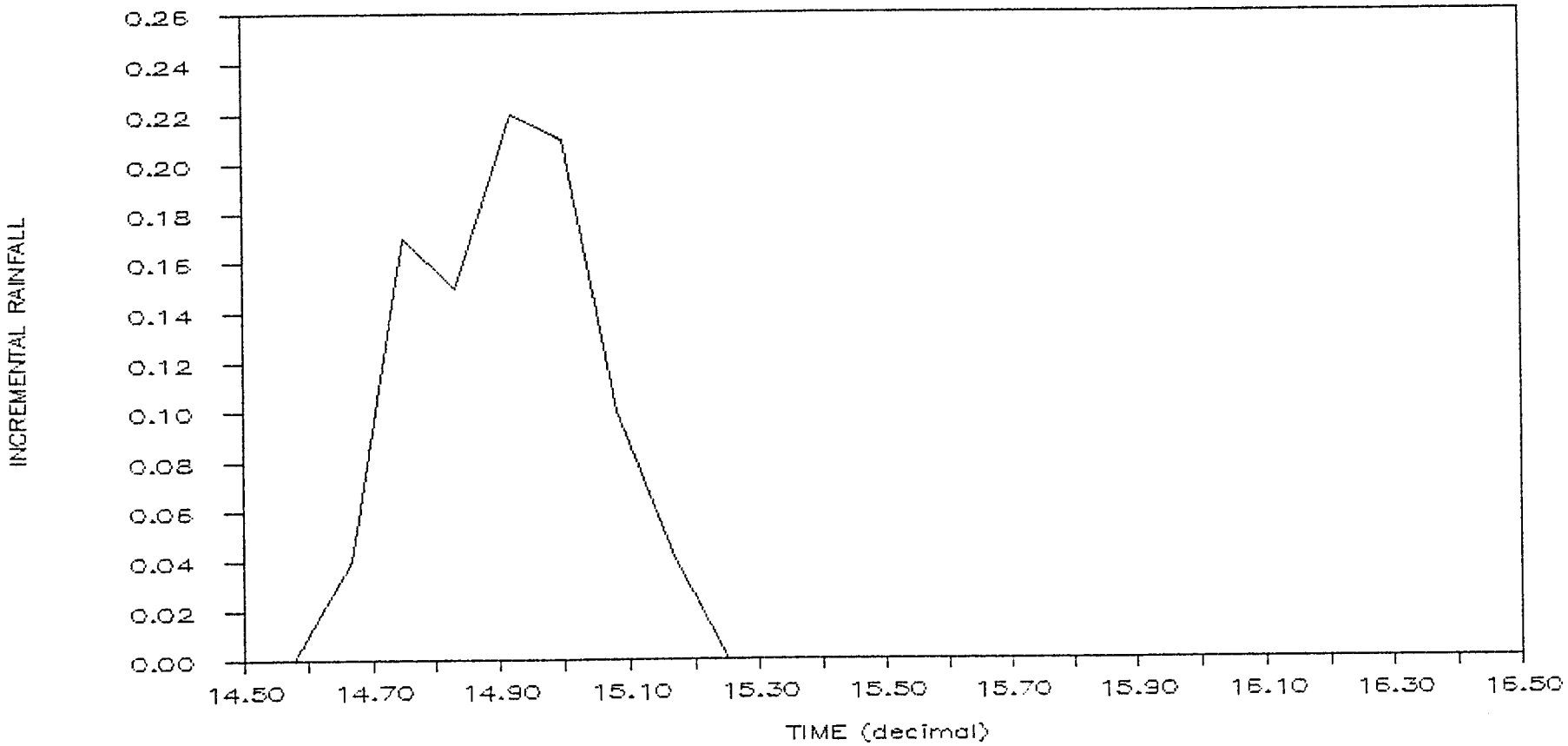
116th Ave and Claude Court

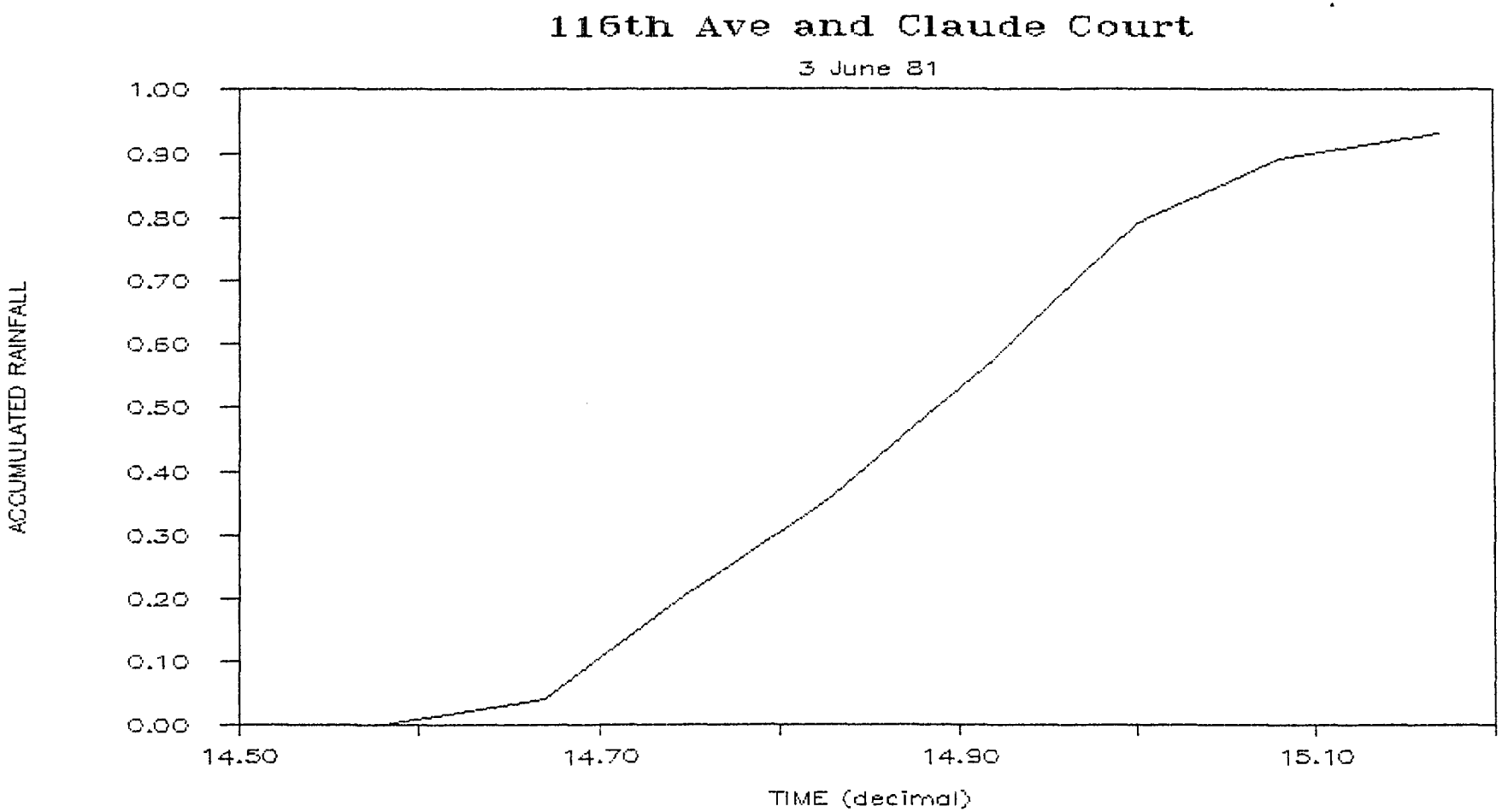
3 June 81



116th Ave and Claude Court

3 June 81

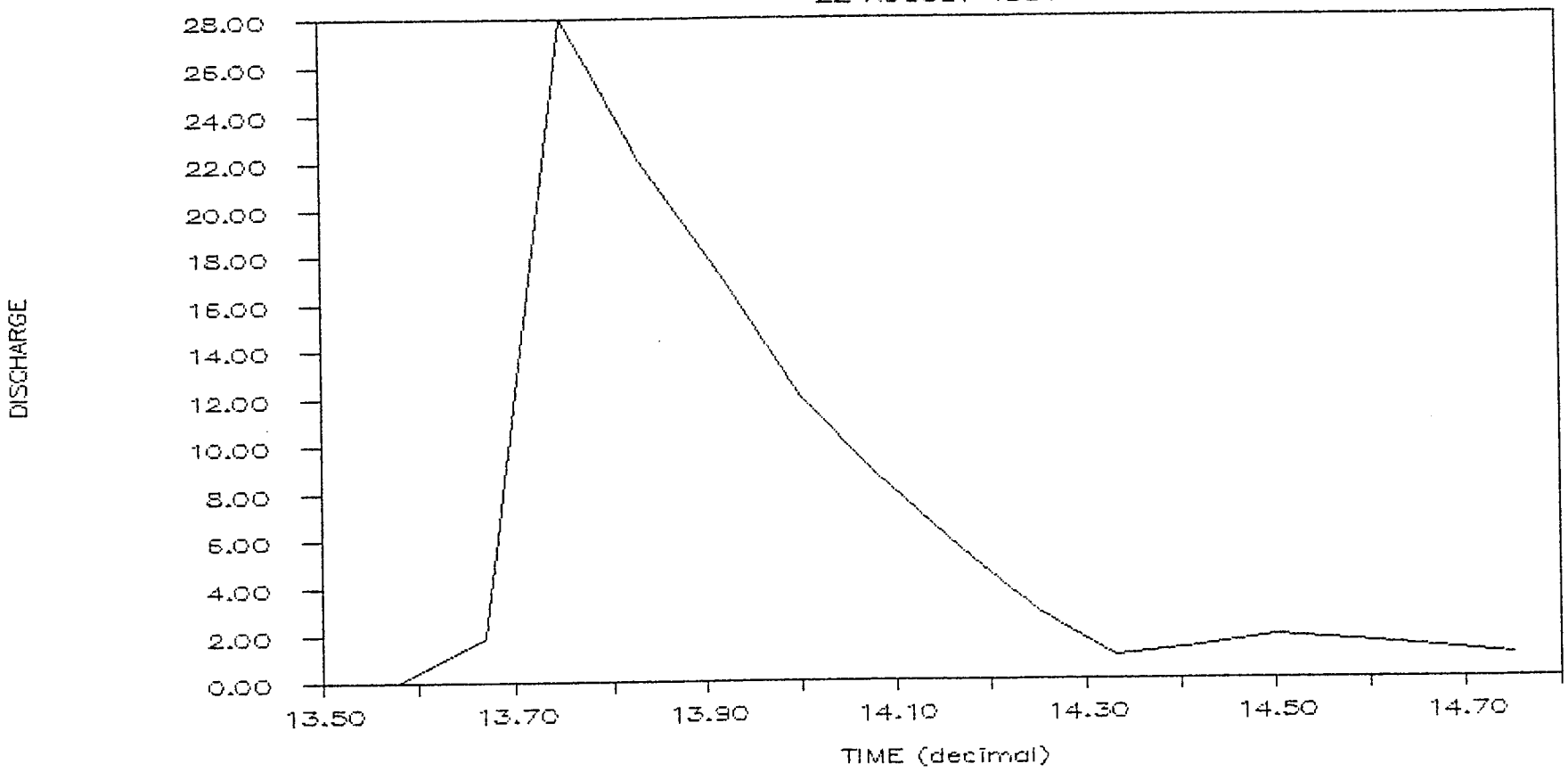



116th Ave and Claude Court
3 June 81
ACCUMULATED RAINFALL
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
14.50
14.70
14.90
15.10
TIME (decimal)

DENVER DATA	DATE	TIME	Q	P1	SUM P1	P2	SUM P2	P3	SUM P3
116th Ave and Claude Ct.	22-Aug-81	1330	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1335	0.00	0.03	0.03	0.02	0.02	0.05	0.05
		1340	1.90	0.08	0.11	0.10	0.12	0.14	0.19
		1345	28.00	0.09	0.20	0.08	0.20	0.10	0.29
		1350	22.00	0.06	0.26	0.04	0.24	0.01	0.30
		1355	17.00	0.04	0.30	0.04	0.28	0.02	0.32
		1400	12.00	0.01	0.31	0.01	0.29	0.02	0.34
		1405	8.70	0.01	0.32	0.00	0.29	0.00	0.34
		1410	5.50	0.00	0.32	0.00	0.29	0.00	0.34
		1415	2.90	0.00	0.32	0.00	0.29	0.00	0.34
		1420	0.98	0.00	0.32	0.00	0.29	0.00	0.34
		1425	1.40	0.00	0.32	0.00	0.29	0.01	0.35
		1430	1.80	0.00	0.32	0.00	0.29	0.01	0.36
		1435	1.60	0.00	0.32	0.00	0.29	0.01	0.37
		1440	1.30	0.00	0.32	0.00	0.29	0.00	0.37
		1445	0.98	0.00	0.32	0.00	0.29	0.00	0.37

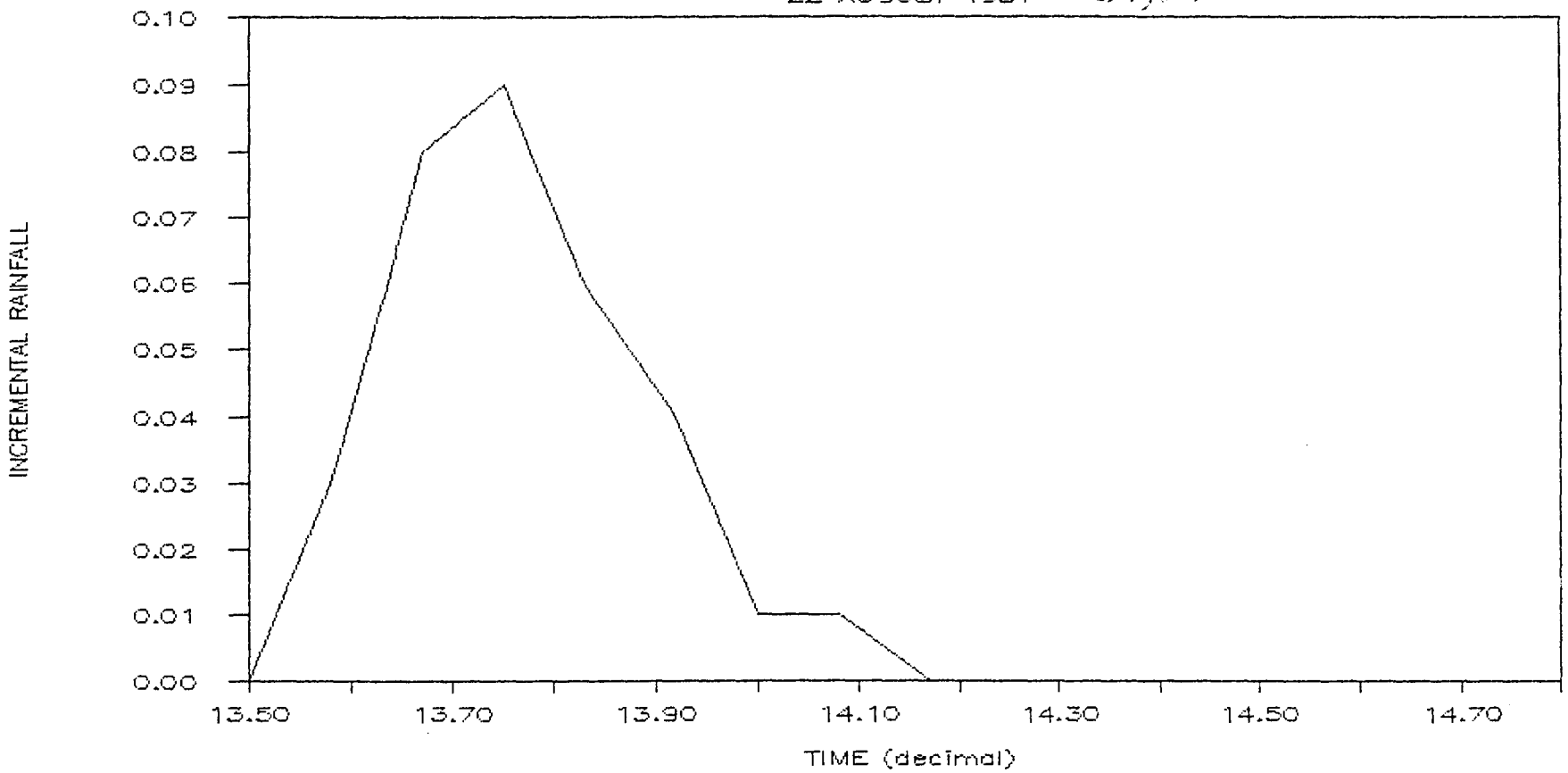
116th Ave and Claude Court

22 AUGUST 1981



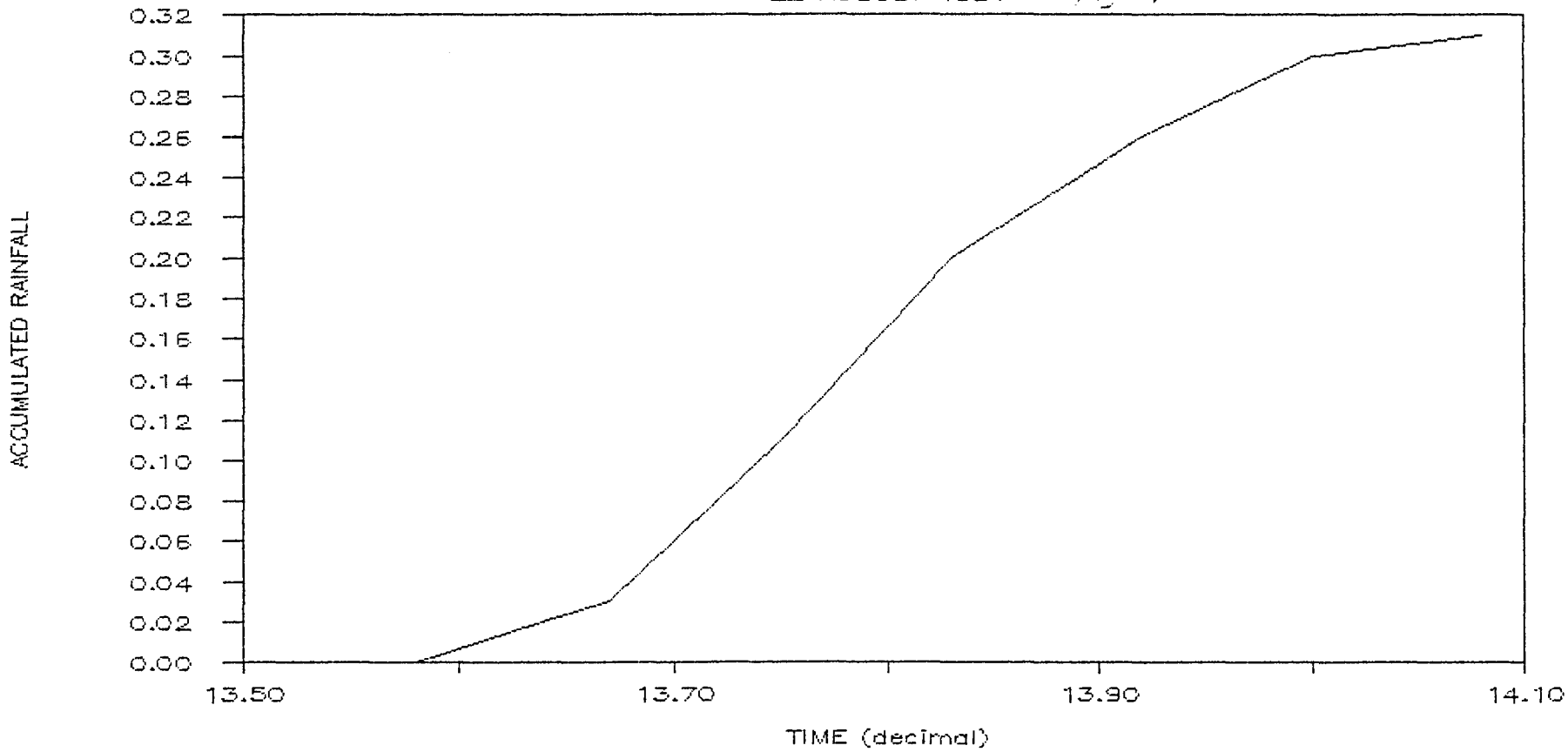
116th Ave and Claude Court

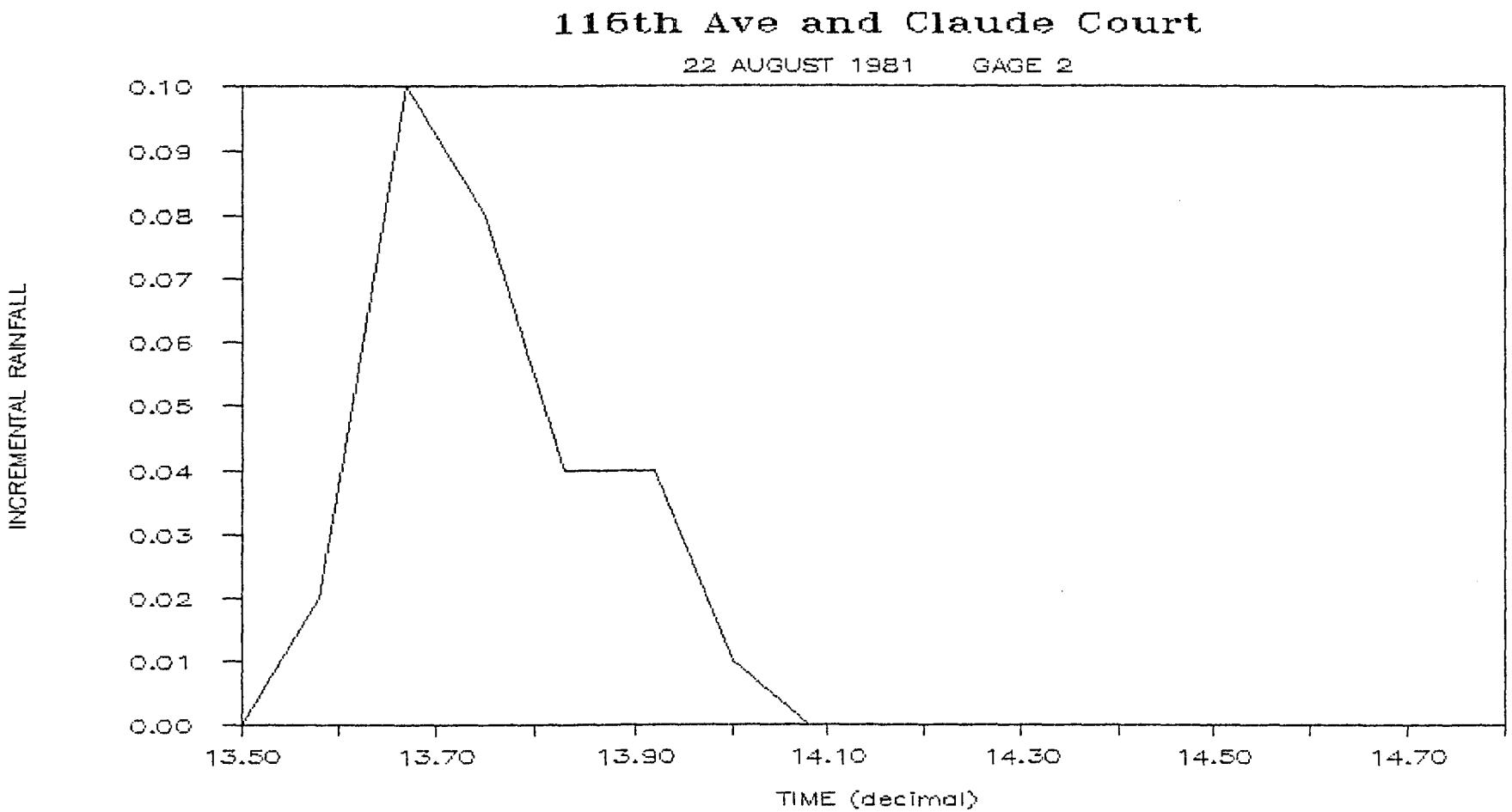
22 AUGUST 1981 Gage 1



116th Ave and Claude Court

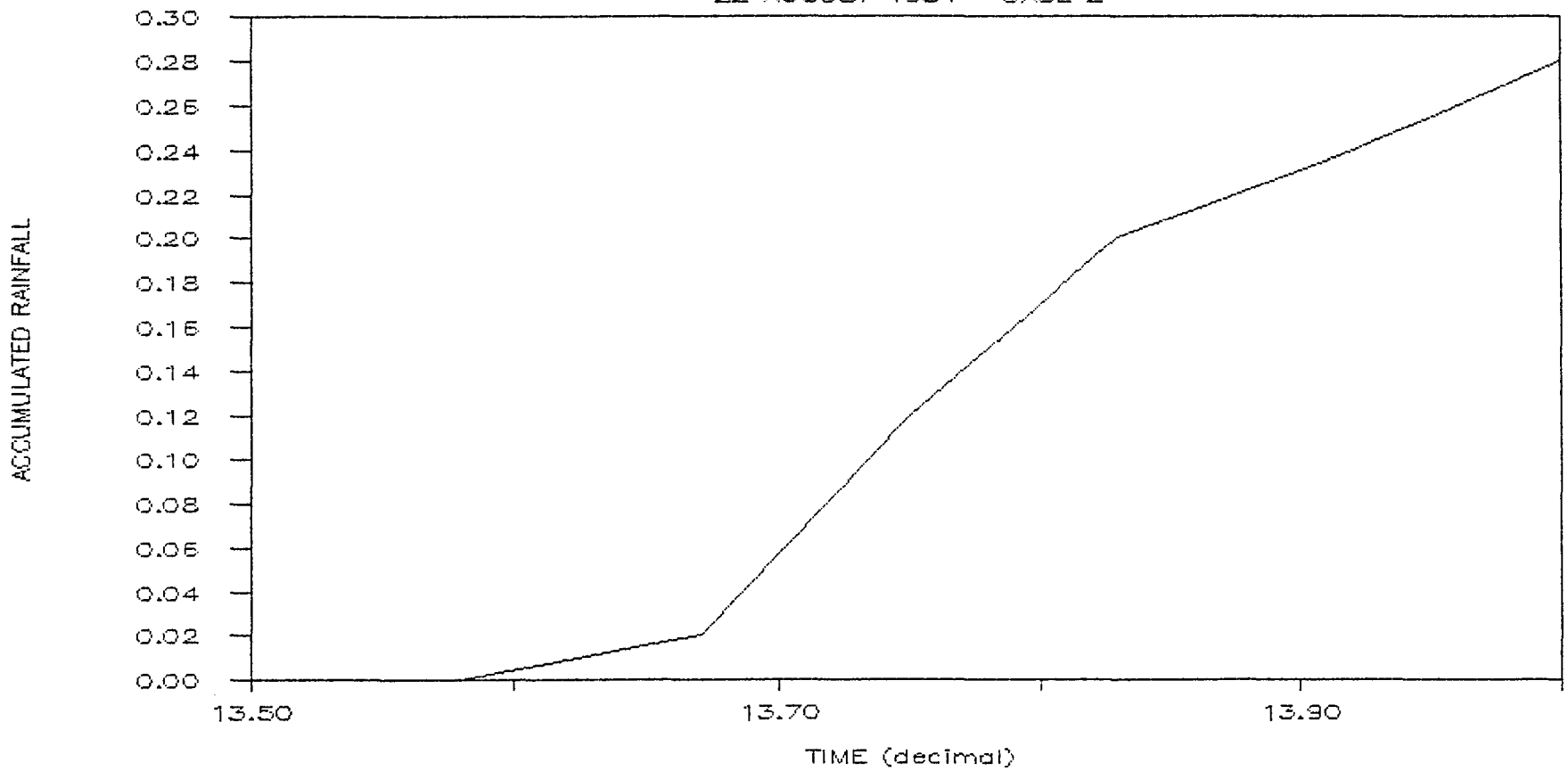
22 AUGUST 1981 Page 1

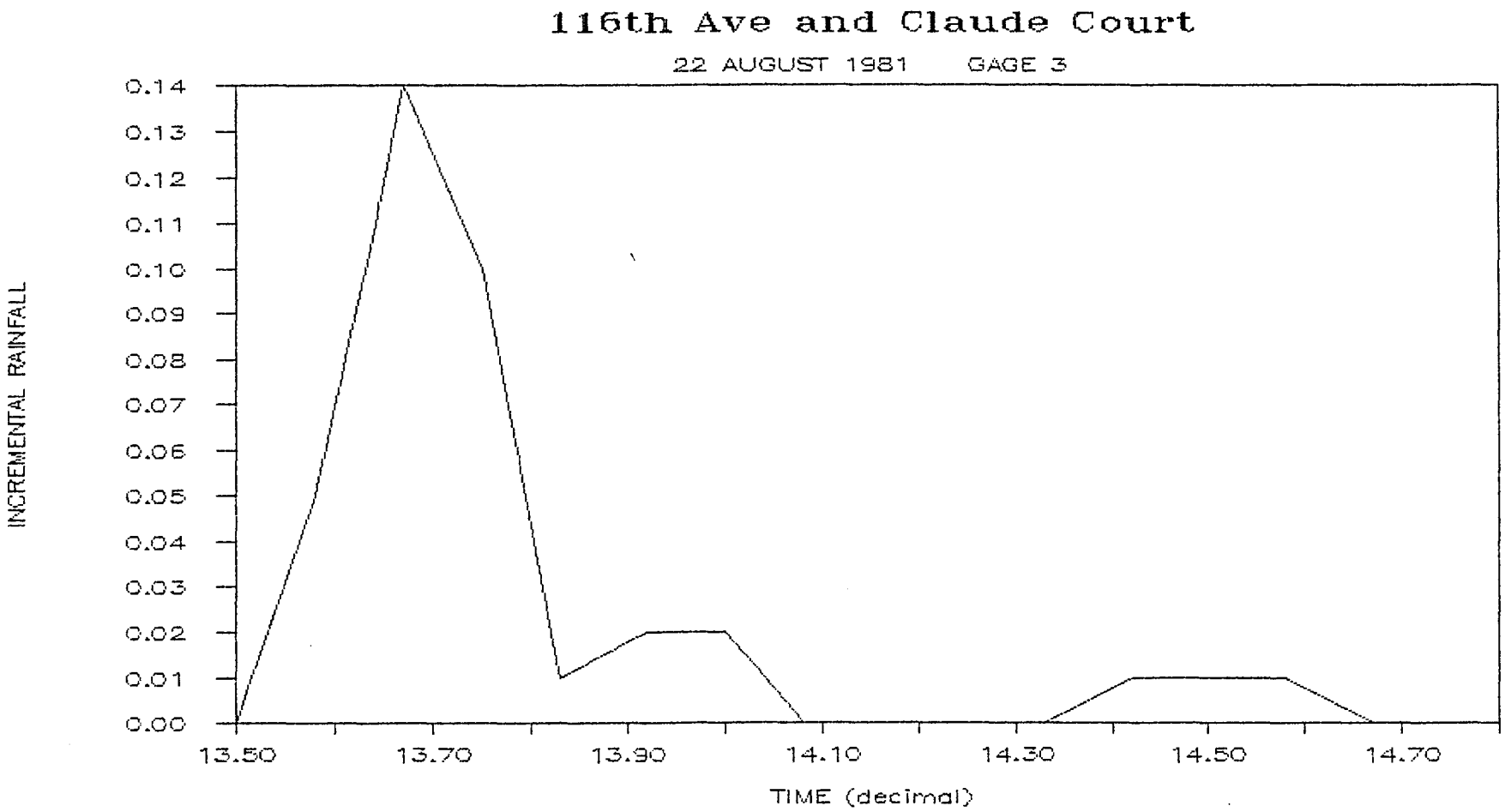



116th Ave and Claude Court
22 AUGUST 1981 GAGE 2
INCREMENTAL RAINFALL
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
13.50
13.70
13.90
14.10
14.30
14.50
14.70
TIME (decimal)

116th Ave and Claude Court

22 AUGUST 1981 GAGE 2




116th Ave and Claude Court
22 AUGUST 1981 GAGE 3
INCREMENTAL RAINFALL
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
13.50
13.70
13.90
14.10
14.30
14.50
14.70
TIME (decimal)

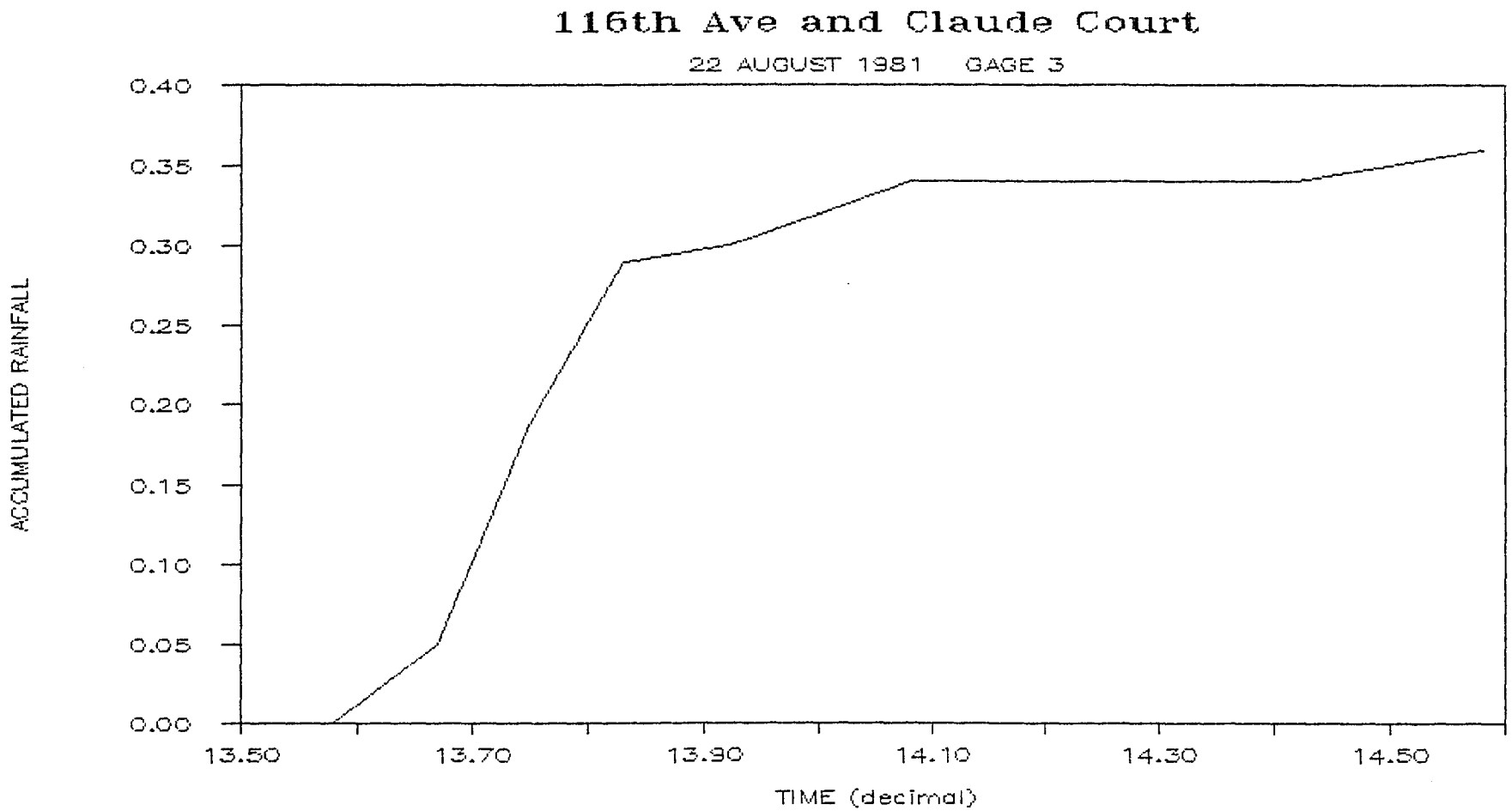

116th Ave and Claude Court
22 AUGUST 1981 GAGE 3
ACCUMULATED RAINFALL
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
13.50
13.70
13.90
14.10
14.30
14.50
TIME (decimal)

Table 228.--Basin characteristics of
06720420 Storm drain at 116th Avenue and Claude Court
at Northglenn, Colo.

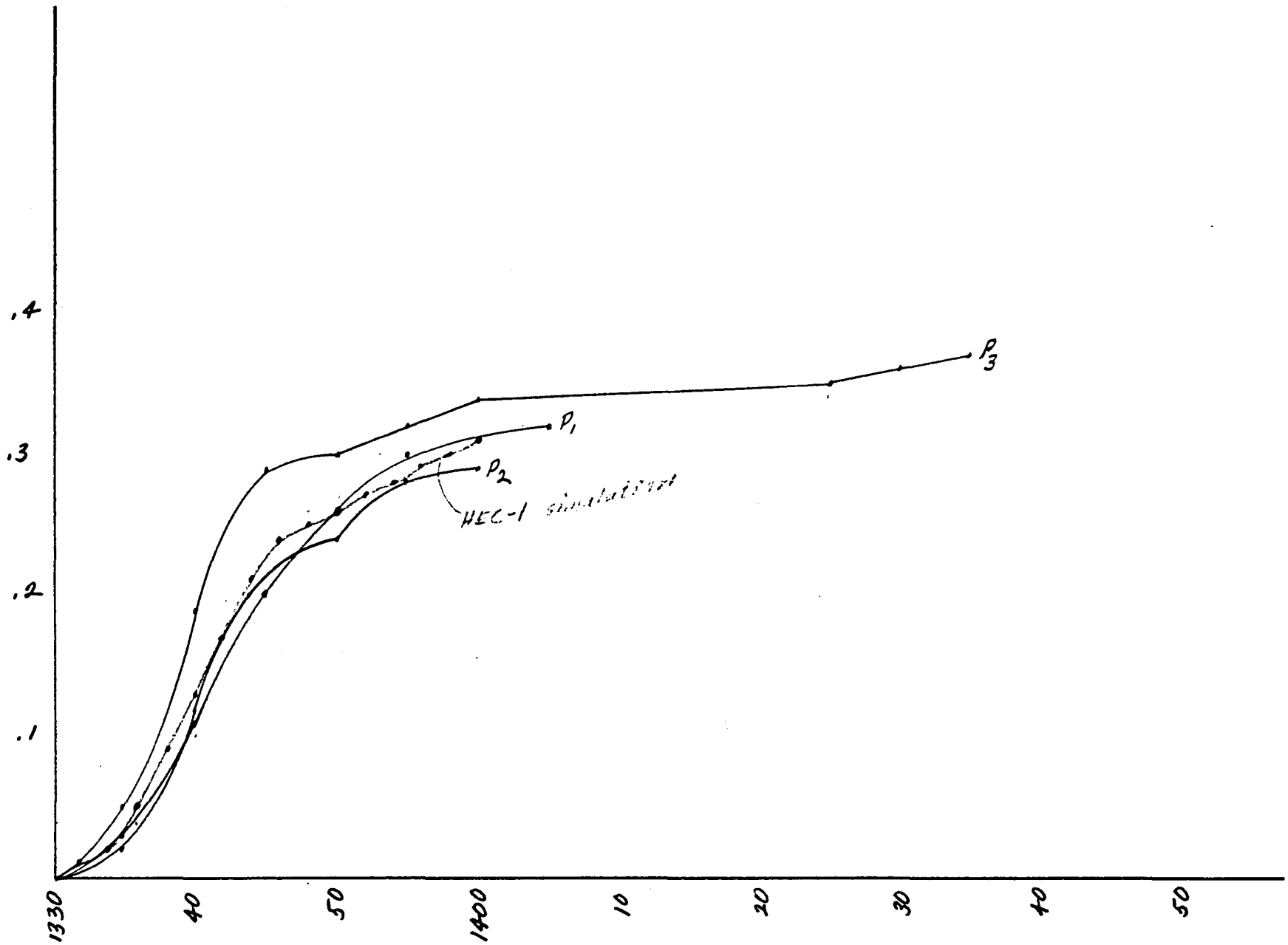
[Dashes indicate data not available]

Characteristic	Value
Contributing drainage area, in acres	170
Impervious area, in percentage of contributing drainage area	37
Effective impervious area, in percentage of contributing drainage area	24
Average basin slope, in feet per mile	-
Main conveyance slope, in feet per mile	-
Population density, in number of people per square mile	9,000
Street density, in miles of lanes per square mile	-
Percentage of contributing drainage with the following land uses:	
Rural and pasture	0
Agricultural	0
Low density residential	0
Medium density residential	100
High density residential	0
Commercial	0
Industrial	0
Construction	0
Idle or vacant	0
Wetland	0
Parkland	0
Detention storage, in acre-feet	-
Percentage of contributing drainage area upstream of detention storage	-
Percentage of contributing drainage area drained by a storm-sewer system	-
Percentage of streets with curb and gutter drainage	-
Percentage of streets with ditch and swale drainage	-
Mean annual rainfall, in inches	16
Ten year 1-hour rainfall intensity, in inches per hour	-

Storm Drain at 116th Avenue and Claude Court, at Northglenn

The storm drain at 116th Avenue and Claude Court drains a single-family residential area in northeast Northglenn. The basin area consists of 167 acres, with 1/6-acre lots, and the effective impervious area is 24 percent. The one school and church in the basin are considered functional parts of the single-family residential area. The monitoring site is located at the storm drain east of 116th Avenue and Claude Court. A 4-foot Parshall flume is used to measure flow.

Three rain gages are located in the basin. Rain gage 1 is located at the monitoring shelter, rain gage 2 is located at Northeast Junior High School, and rain gage 3 is located at Calvary Community Baptist Church (pl. 6).



Rainfall Dist.
DIIG 2

21 Oct 87

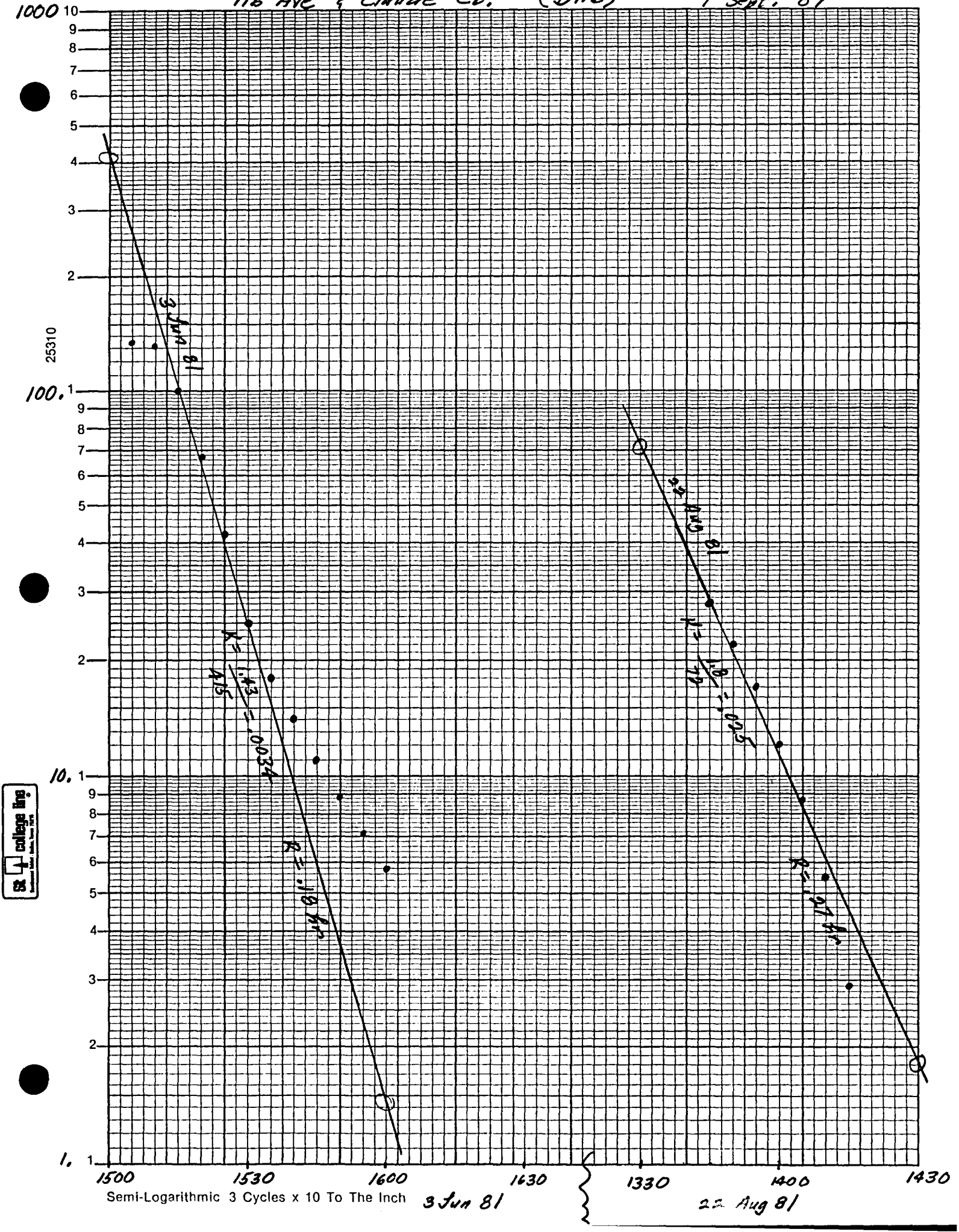
20 Oct 87

Analysis of Effective Impervious Area
116th Ave & Claude Ct.

	Storm Date (1)	Rainfall Avg. in. (2)	Rainfall Max. in (3)	Runoff Volume ac-ft (4)	Runoff Qp cfs (5)		Ae acres (6)	
	19-20 April 81	.36	.40	.68	6.6		22.7	
145-1710	3 May 81	.28	.29	.71	6.1	X	30.4	high intens. burst
	12-13 May 81	.315	.33	.77	4.2		29.3	
	12 July 81	.09	.10	.16	2.9		21.3	
	16 Aug 81	.11	.15	.17	4.2		18.6	
	29 Aug 81	.09	.11	.16	3.3		21.3	
						Avg =	22.6	acres

$$\% \text{ eff. imp. area} = \frac{22.6}{170} \times 100 = 13.3\ \%$$

116 Ave & Claude Ct. (D116) 9 Sept. 87



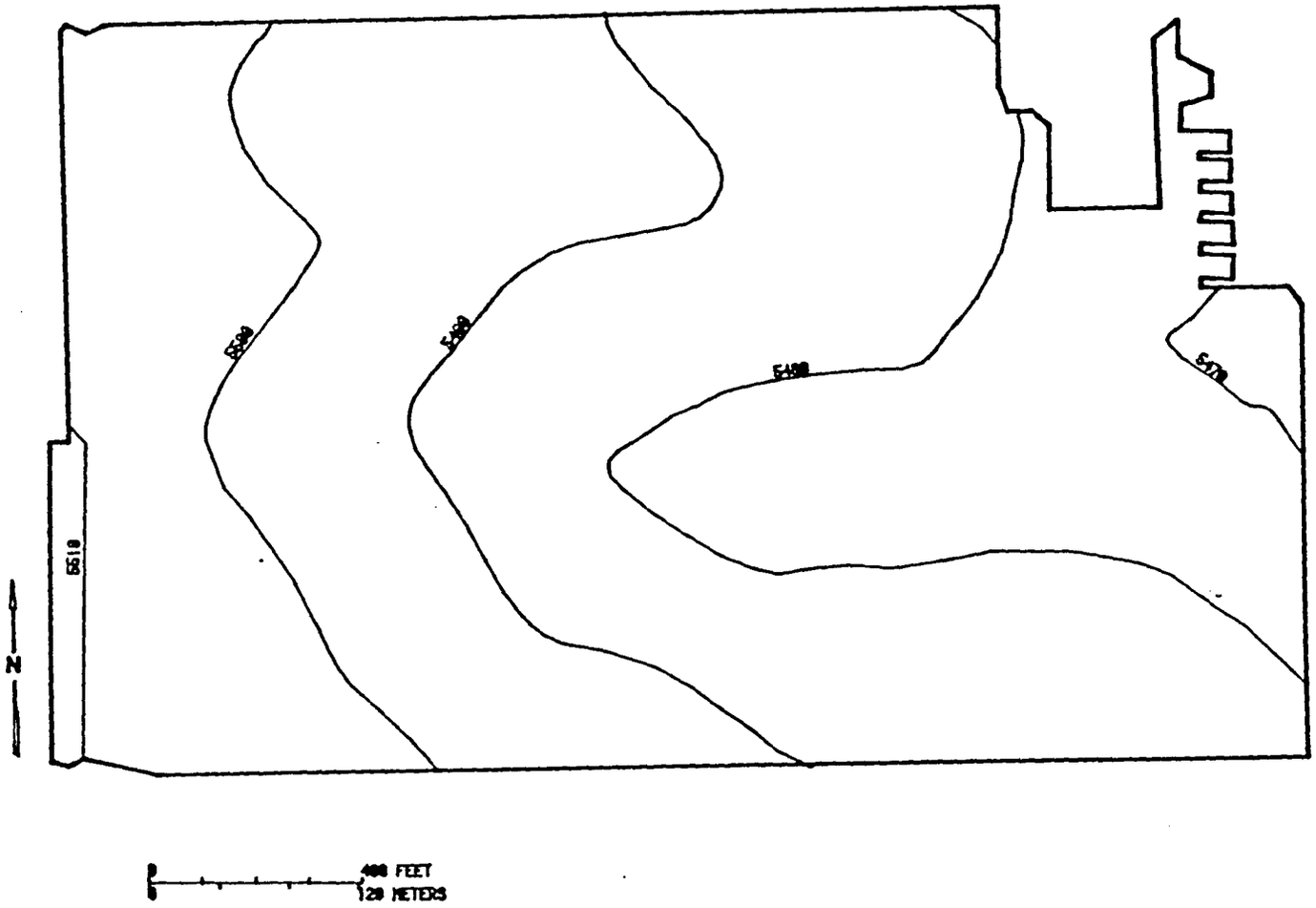
Flood Reconstitution for Denver Villa Italia DVI 1

Storm Event 20 April 80

Runoff: depth = .47 inches, Q_p = 77 cfs at t_p = .58 hours

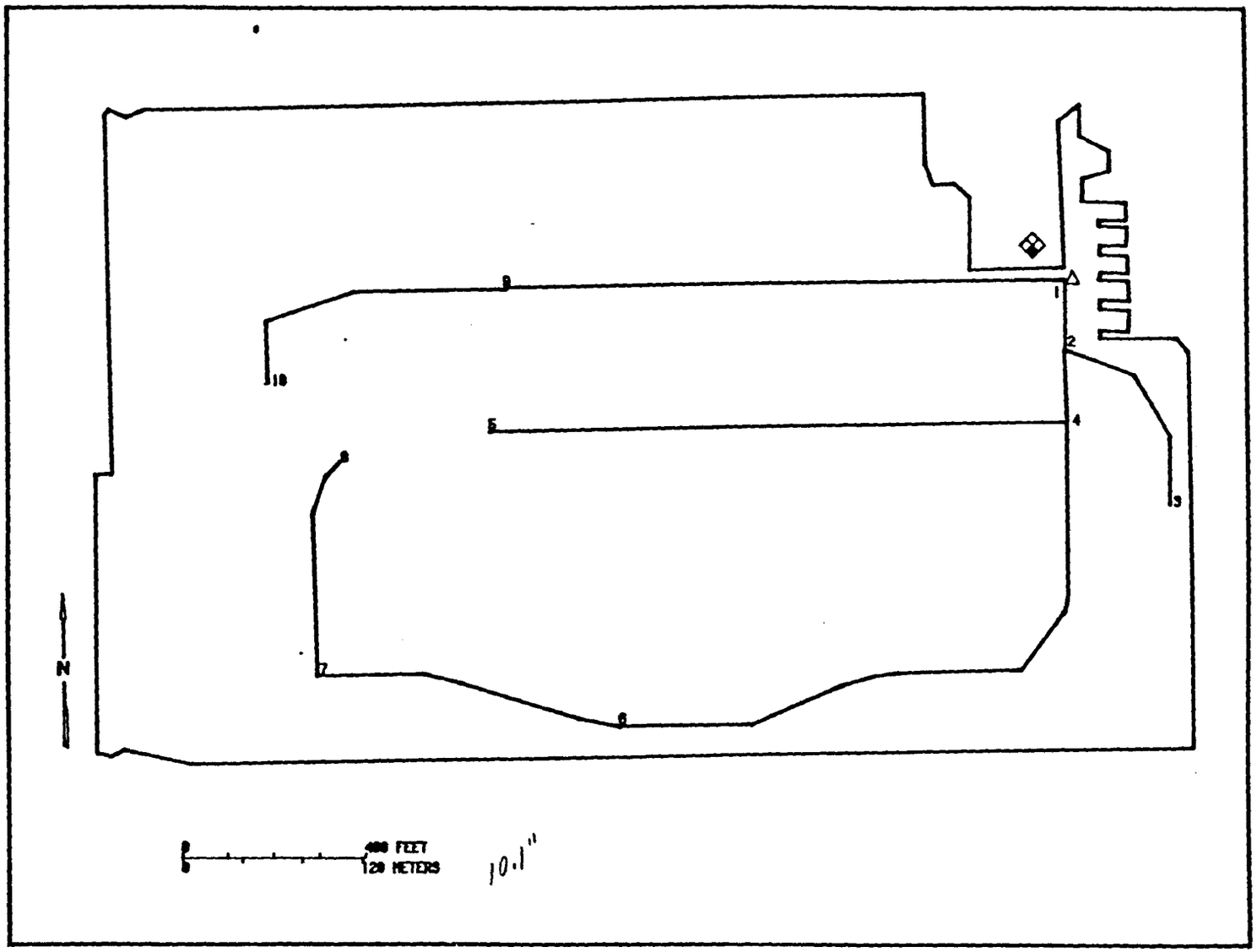
$R_{recession}$ = .10 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
77.0	91	.54	5	D	runoff = 1.12 * rainfall	70	.58	.12	.19	1.0	.2	Ø1	
"	"	"	"	N-2	"	70	.58	.14	.19	1.0	.2	Ø2	
"	"	"	2	d-1	"	71	.53	.14	.24	1.0	.2	Ø3	
"	82	"	"	D	OK	70	.57	.14	.18	.74	.15	Ø4	← best



Denver, Colorado
394236105042400 - Villa Italia
Storm Drain at Lakewood, Colorado

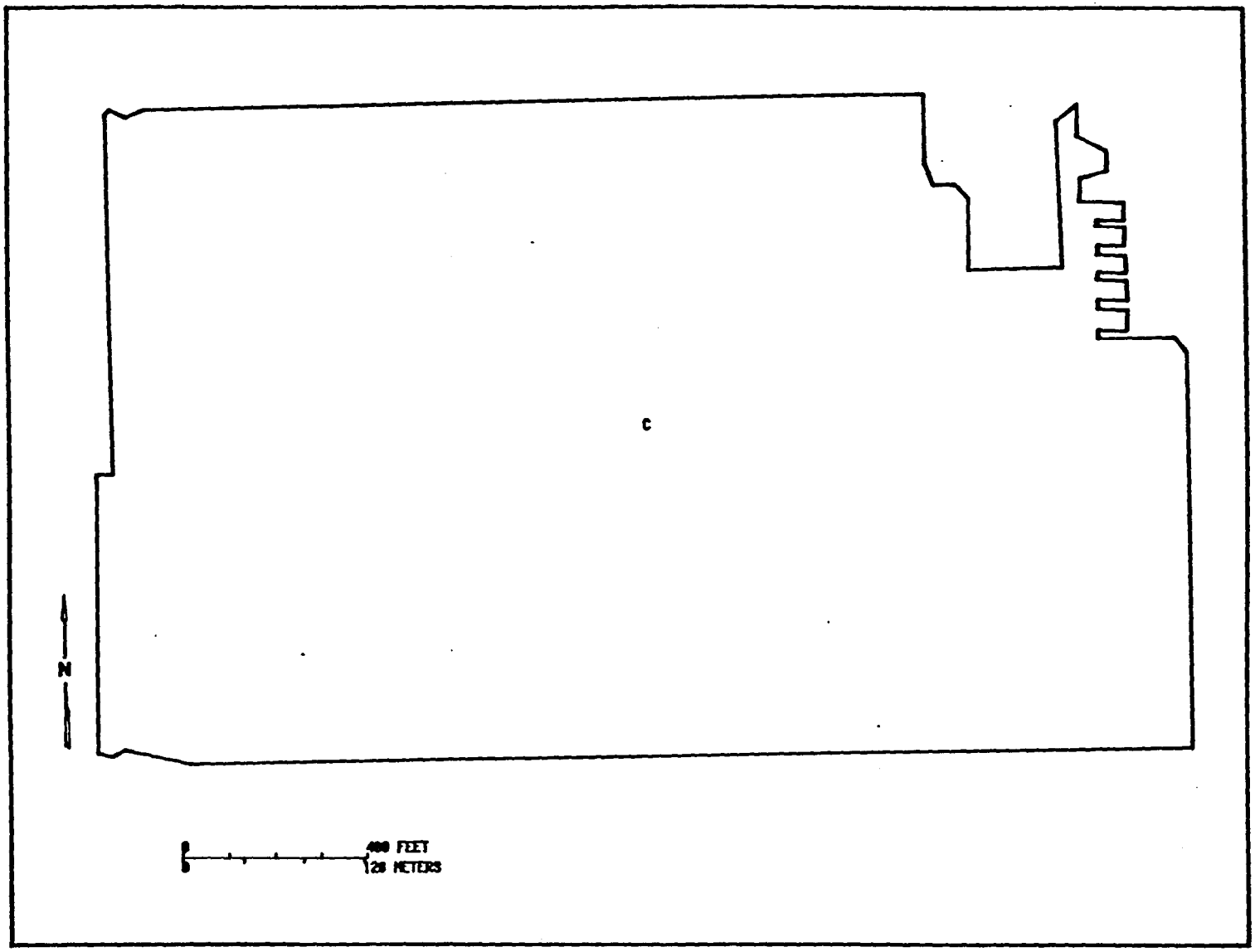
Topography Map



Denver, Colorado 394236105042400 - Villa Italia Storm Drain at Lakewood, Colorado	Drainage Map Tot. Drainage Area - 0.12

PIPE DATA FOR SITE : 05042400

Key Nos.		Shape	Dimension (inches)	Slope (ft/ft)	Length (feet)	Material
1	2	Circular	27	0.014	145	?
2	3	Circular	15	0.021	466	?
2	4	Circular	24	0.014	155	?
4	5	Circular	10	0.012	1254	?
4	6	Circular	24	0.008	1716	?
6	7	Circular	21	0.008	700	?
7	8	Circular	21	0.004	550	?
1	9	Circular	24	0.031	1250	?
9	10	Circular	21	0.020	650	?



	Land Use Map
Denver, Colorado 394236105042400 - Villa Italia Storm Drain at Lakewood, Colorado	Impervious Area - 91.00 Population Density - 0 Detention Storage - 0.00

Table 83.--Subcatchment data for Villa Italia Storm Drain at Lakewood, for use with U.S. Geological Survey's Distributed Routing Rainfall-Runoff Model, Version II

ub-chment mber	Drainage area (acres)	Gutter or pipe for drainage	Overland flow length (ft)	Percent effective impervious area	Slope (ft/ft)	Manning *n* value	Thiessen coefficient Rain gage 1
1	7.9	21	626	89.6	0.060	0.013	1.0
2	14.2	27	952	76.1	.023	.013	1.0
3	8.1	22	504	100	.012	.013	1.0
4	5.2	26	181	100	.010	.013	1.0
5	7.6	28	788	84.5	.008	.013	1.0
6	11.9	23	302	100	.011	.013	1.0
7	11.7	29	614	90.9	.022	.013	1.0
8	5.1	24	717	100	.017	.013	1.0
9	1.8	31	506	100	.005	.013	1.0

Avg=.019

Table 84.--Gutter and pipe data for Villa italia Storm Drain at Lakewood, for use with U.S. Geological Survey's Distributed Routing Rainfall-Runoff Model, Version II

ter pipe ber	Gutter or pipe for drainage	Length (ft)	Slope (ft/ft)	Type[1]	Left side slope (ft/ft)	Right side slope (ft/ft)	Diameter (ft)	Manning *n* value
1	22	550	0.004	C	---	---	1.75	0.016
2	23	700	.008	C	---	---	1.75	.016
3	31	1,716	.008	C	---	---	2.00	.016
4	25	310	.021	C	---	---	1.25	.016
5	31	156	.021	C	---	---	1.25	.016
6	30	1,254	.012	C	---	---	.83	.016
7	28	650	.020	C	---	---	1.75	.016
8	29	420	.031	C	---	---	2.00	.016
9	--	830	.031	C	---	---	2.00	.016
0	31	155	.014	C	---	---	2.00	.016
1	--	145	.014	C	---	---	2.25	.016

[1]C=Circular pipe.

Table 24.--Basin characteristics of
394236105042400 Villa Italia storm drain at Lakewood, Colo.

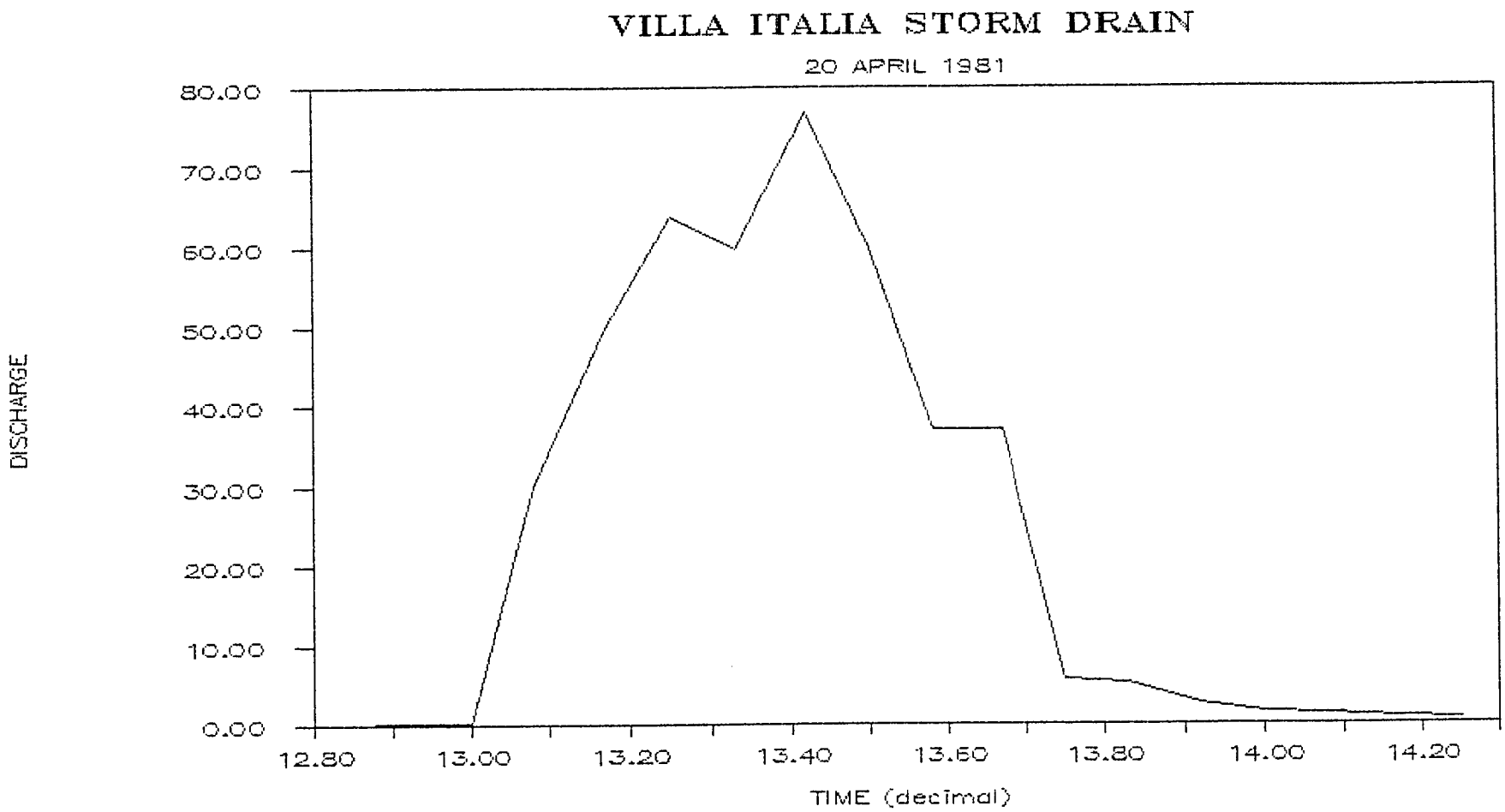
[Dashes indicate data not available]

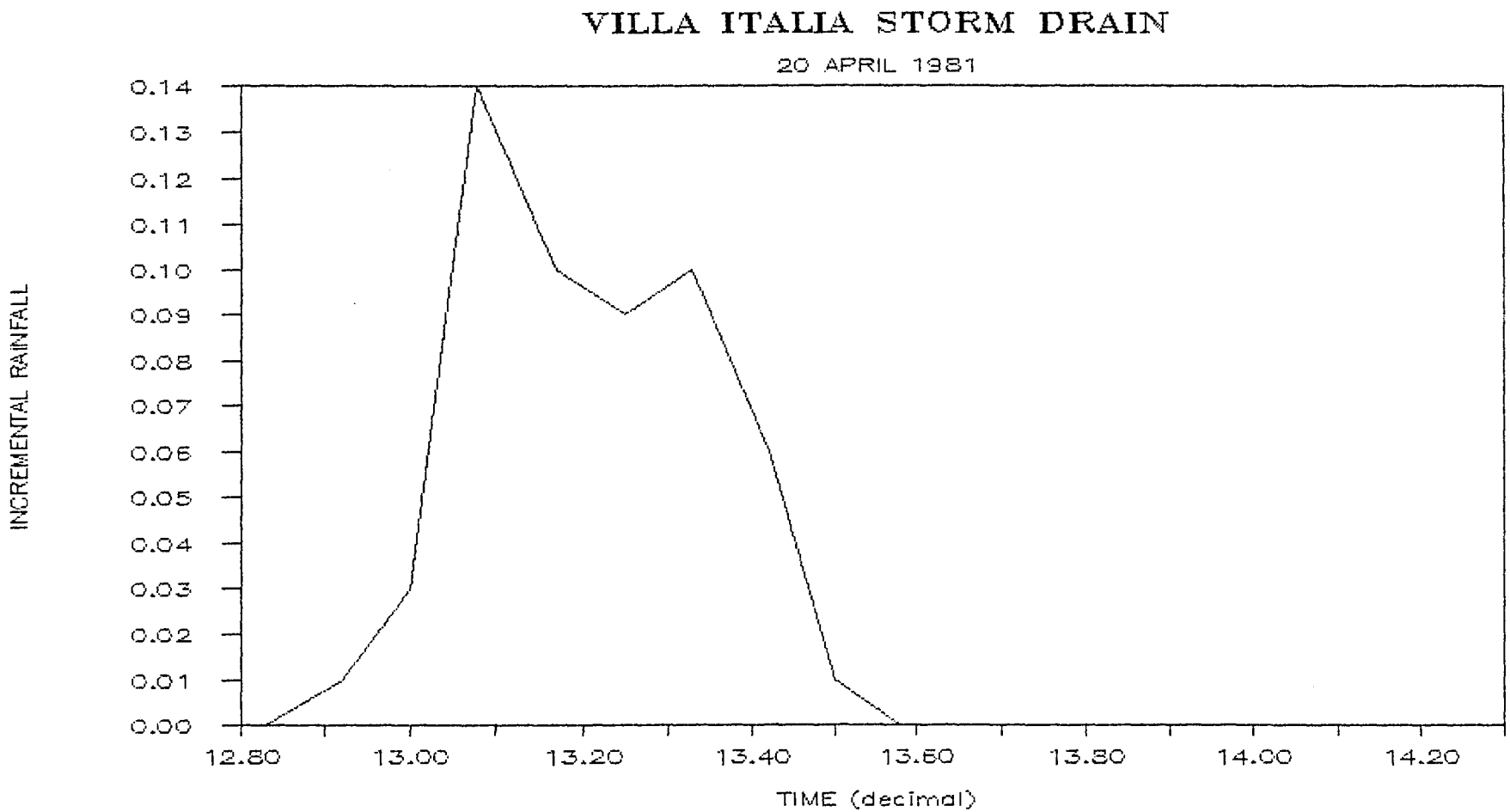
Characteristic	Value
Contributing drainage area, in acres	77
Impervious area, in percentage of contributing drainage area	91
Effective impervious area, in percentage of contributing drainage area	91
Average basin slope, in feet per mile	-
Main conveyance slope, in feet per mile	-
Population density, in number of people per square mile	0
Street density, in miles of lanes per square mile	-
Percentage of contributing drainage with the following land uses:	
Rural and pasture	0
Agricultural	0
Low density residential	0
Medium density residential	0
High density residential	0
Commercial	100
Industrial	0
Construction	0
Idle or vacant	0
Wetland	0
Parkland	0
Detention storage, in acre-feet	0
Percentage of contributing drainage area upstream of detention storage	-
Percentage of contributing drainage area drained by a storm-sewer system	-
Percentage of streets with curb and gutter drainage	-
Percentage of streets with ditch and swale drainage	-
Mean annual rainfall, in inches	16
Ten year 1-hour rainfall intensity, in inches per hour	-

Villa Italia Storm Drain at Lakewood

Villa Italia Storm Drain is in a light commercial area in Lakewood. The basin consists of 74 acres, and the effective impervious area is 91 percent. The monitoring site is located near a 42-inch storm drain on the east side of the Villa Italia Shopping Center. A velocity-modified flowmeter is used to determine flow. One rain gage is located in the basin on the roof of World of Sleep Store (pl. 7).

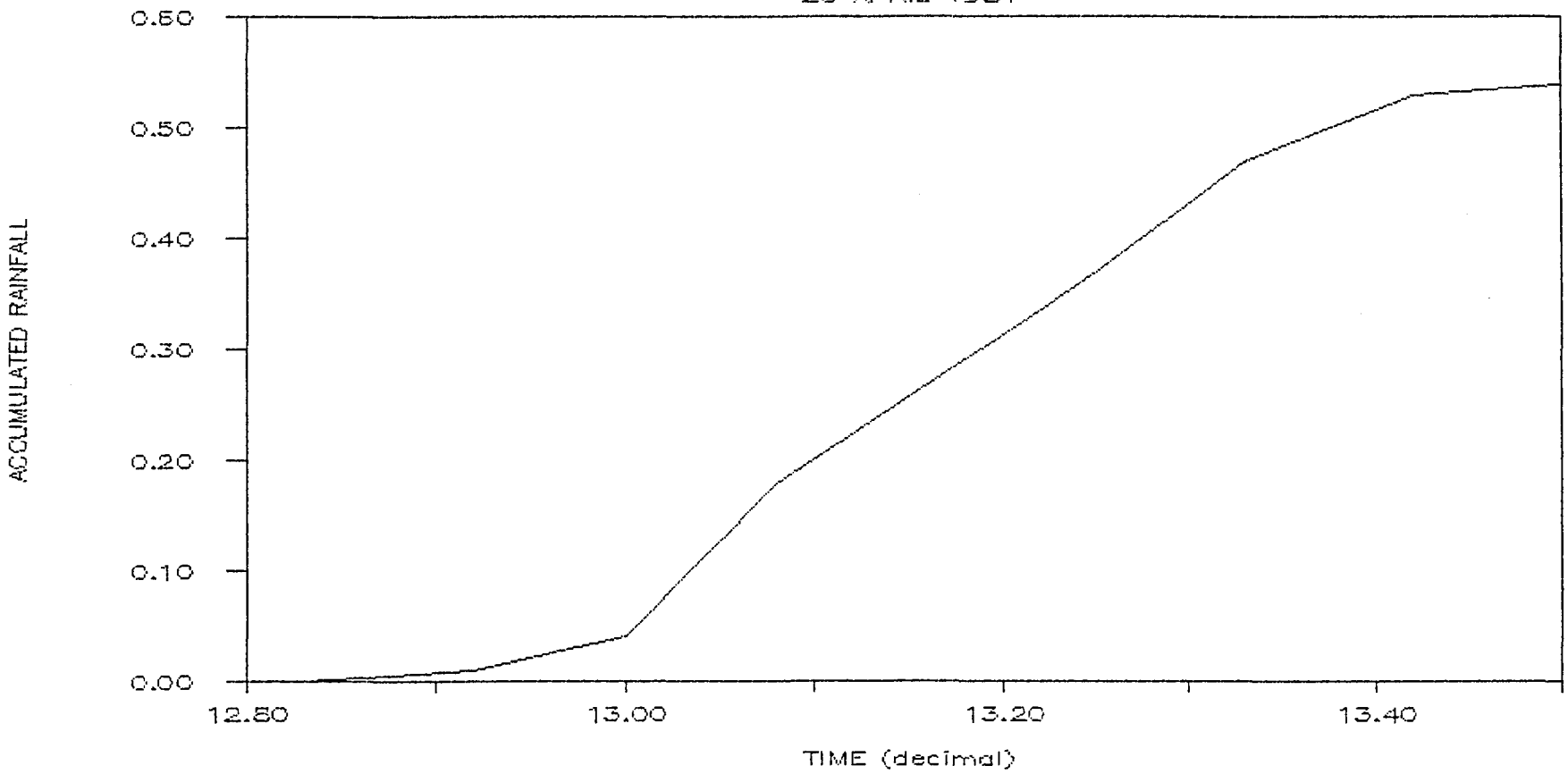
DENVER DATA	DATE	TIME	Q	P1	SUM P1
Villa Italia Storm Drain	20-Apr-81	1250	0.00	0.00	0.00
		1255	0.23	0.01	0.01
		1300	0.23	0.03	0.04
		1305	30.00	0.14	0.18
		1310	50.00	0.10	0.28
		1315	64.00	0.09	0.37
		1320	60.00	0.10	0.47
		1325	77.00	0.06	0.53
		1330	60.00	0.01	0.54
		1335	37.00	0.00	0.54
		1340	37.00	0.00	0.54
		1345	5.70	0.00	0.54
		1350	5.30	0.00	0.54
		1355	2.60	0.00	0.54
		1400	1.50	0.00	0.54
		1405	1.30	0.00	0.54
		1410	1.00	0.00	0.54
		1415	0.70	0.00	0.54


VILLA ITALIA STORM DRAIN
20 APRIL 1981
DISCHARGE
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
12.80
13.00
13.20
13.40
13.60
13.80
14.00
14.20
TIME (decimal)

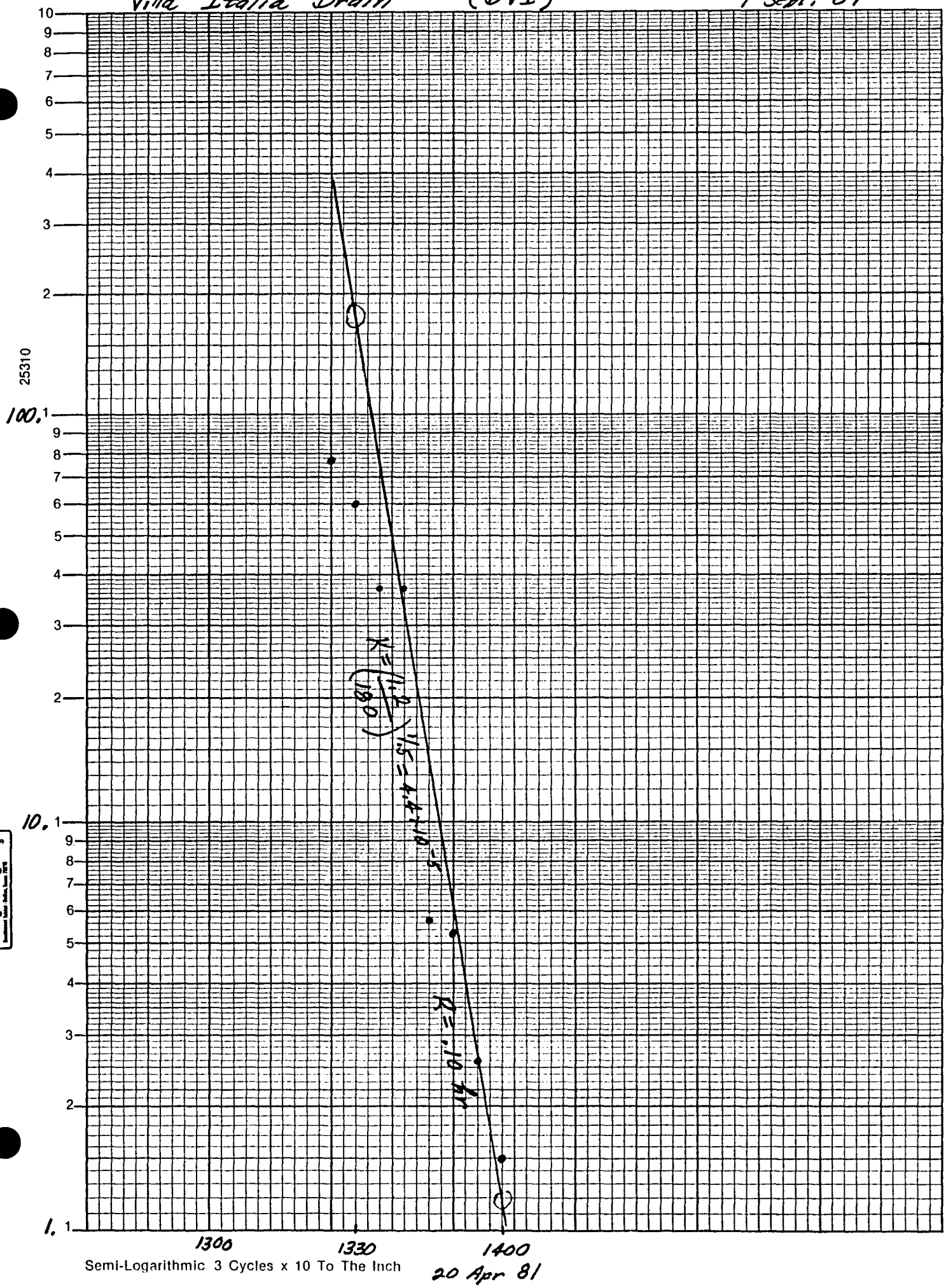

VILLA ITALIA STORM DRAIN
20 APRIL 1981
INCREMENTAL RAINFALL
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
12.80
13.00
13.20
13.40
13.60
13.80
14.00
14.20
TIME (decimal)

VILLA ITALIA STORM DRAIN

20 APRIL 1981



Villa Italia Drain (DVI) 9 Sept. 87



Semi-Logarithmic 3 Cycles x 10 To The Inch

20 Apr 81

Flood Reconstitution for Denver Concourse D DCD1

Storm Event 1 Aug 76

Runoff: depth = 1.78 inches, Q_p = 285 cfs at t_p = .67 hours

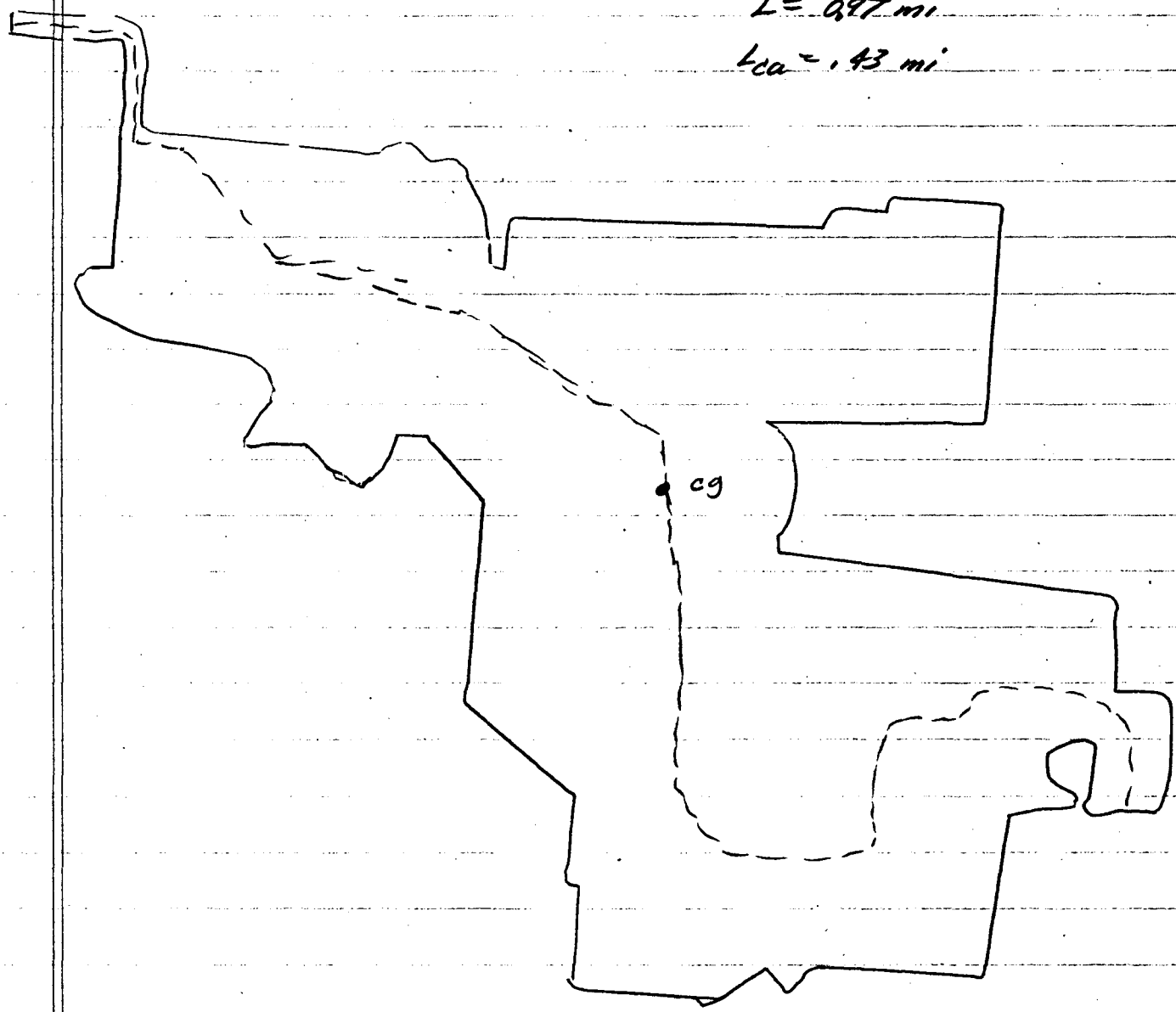
$R_{recession}$ = .20 hrs

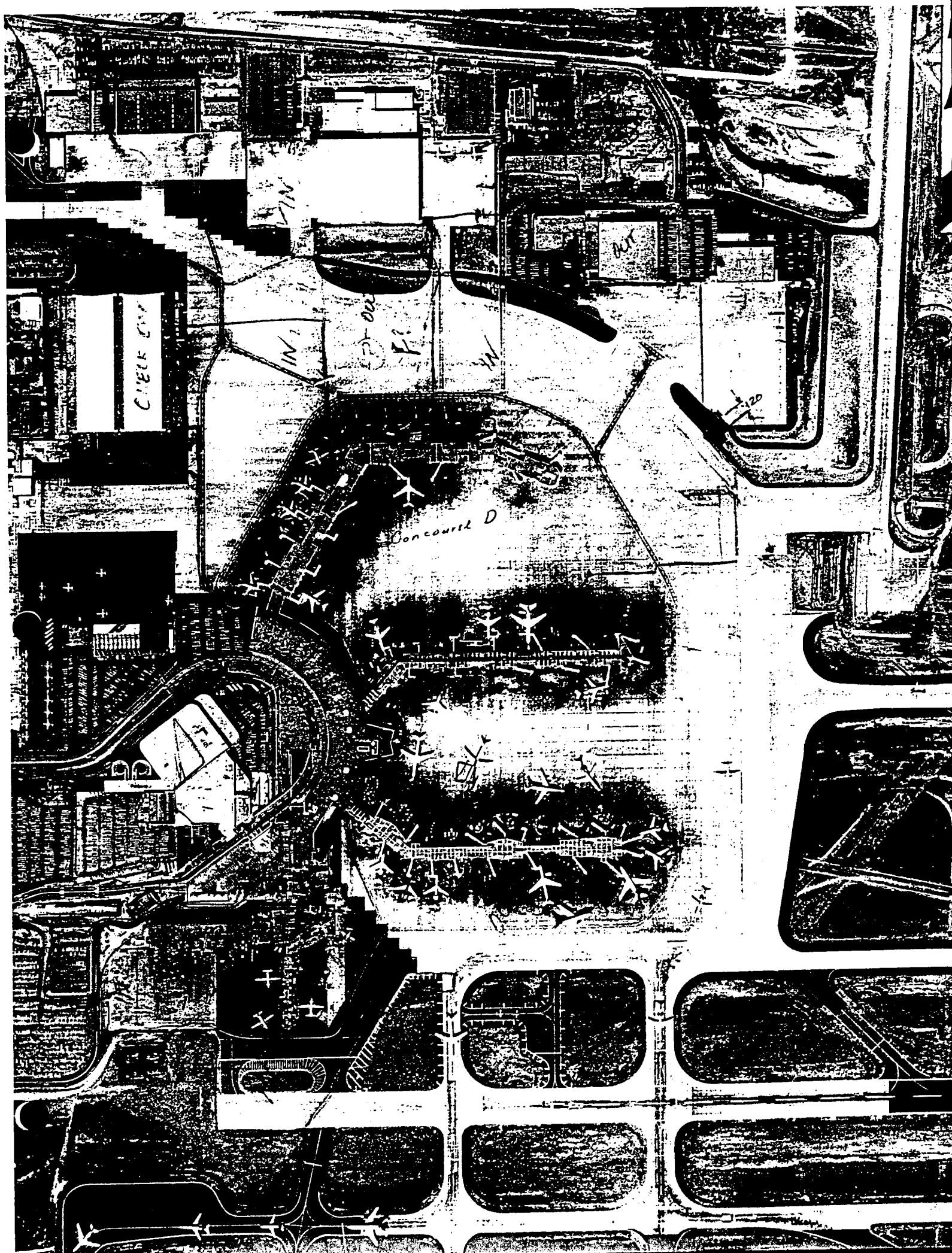
INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
96.0	100	1.97	5	D	runoff = 1.10 x rainfall	267	.67	.15	.25	.61	.12	Ø1	
"	90	"	2	"		253	.63	.18	.21	1.62	.46	Ø2	← best

Concourse D

$L = 0.97$ mi

$L_{ca} = .43$ mi




Concourse D

06714300 CONCOURSE D STORM DRAIN AT STAPLETON AIRPORT, AT DENVER, COLO.

LOCATION.--Lat 39°46'08", long 104°53'12", in NE¼NE¼ sec.28, T.3 S., R.67 W., Denver County, on left bank in 72-in (1.82-m) storm sewer, 125 ft (38 m) south of firehouse at Stapleton International Airport, and 510 ft (160 m) upstream from mouth.

DRAINAGE AREA.--0.15 mi^2 (0.39 km^2), revised.

PERIOD OF RECORD.--May 12, 1970, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

REMARKS.--Basin drains runway aprons and hangar facilities at Stapleton International Airport.

STAGE-DISCHARGE RELATION.--Rating developed on basis of flume rating and discharge measurements at discharges of 1.8 ft^3/s (0.051 m^3/s) and 3.9 ft^3/s (0.11 m^3/s).

EXTREMES.--Water year 1975: Maximum discharge, 126 ft^3/s (3.57 m^3/s) June 23; no flow most of year.
Water year 1976: Maximum discharge, 285 ft^3/s (8.07 m^3/s) Aug. 1; no flow most of year.
Water year 1977: Maximum discharge, 123 ft^3/s (3.48 m^3/s) July 20; no flow most of year.
Period of record: Maximum discharge, 285 ft^3/s (8.07 m^3/s) Aug. 1, 1976; no flow most of each year.

RAINFALL OCT. 11-12,1974

RAINFALL, IN INCHES, DURING INDICATED INTERVAL

DATE	TIME	RAINFALL	DATE	TIME	RAINFALL	DATE	TIME	RAI'
10-11	1805	0.02				10-12	1005	
10-11	1815	0.01				10-12	1015	
10-11	1845	0.01	10-12	0010	0.01	10-12	1025	
10-11	1915	0.01	10-12	0030	0.01	10-12	1035	0
10-11	1920	0.01	10-12	0035	0.01	10-12	1045	0
10-11	1925	0.02	10-12	0045	0.01	10-12	1055	0.
10-11	1930	0.01	10-12	0055	0.01	10-12	1110	0.
10-11	1935	0.01	10-12	0120	0.01	10-12	1125	0.
10-11	1940	0.02	10-12	0140	0.01	10-12	1140	0.
10-11	1945	0.04	10-12	0255	0.01	10-12	1200	0.
10-11	1950	0.02	10-12	0450	0.01	10-12	1225	0.0
10-11	1955	0.02	10-12	0550	0.01	10-12	1245	0.0
10-11	2000	0.02	10-12	0600	0.01	10-12	1255	0.01
10-11	2005	0.01	10-12	0610	0.01	10-12	1315	0.01
10-11	2010	0.01	10-12	0625	0.01	10-12	1335	0.01
10-11	2015	0.01	10-12	0640	0.01	10-12	1405	0.01
10-11	2020	0.01	10-12	0650	0.01	10-12	1435	0.01
10-11	2025	0.01	10-12	0700	0.01	10-12	1445	0.01
10-11	2030	0.01	10-12	0710	0.01	10-12	1450	0.02
10-11	2045	0.01	10-12	0725	0.01	10-12	1455	0.01
10-11	2105	0.01	10-12	0735	0.01	10-12	1500	0.01
10-11	2110	0.01	10-12	0745	0.01	10-12	1505	0.01
10-11	2120	0.01	10-12	0750	0.01	10-12	1515	0.01
10-11	2125	0.01	10-12	0800	0.01	10-12	1520	0.01
10-11	2130	0.02	10-12	0810	0.01	10-12	1525	0.01
10-11	2135	0.01	10-12	0820	0.01	10-12	1530	0.01
10-11	2145	0.01	10-12	0830	0.01	10-12	1535	0.01
10-11	2150	0.01	10-12	0835	0.01	10-12	1540	0.01
10-11	2210	0.01	10-12	0845	0.01	10-12	1545	0.02
10-11	2220	0.01	10-12	0850	0.01	10-12	1550	0.01
10-11	2240	0.01	10-12	0855	0.01	10-12	1555	0.01
10-11	2255	0.01	10-12	0900	0.01	10-12	1600	0.01
10-11	2305	0.01	10-12	0905	0.01	10-12	1605	0.01
10-11	2310	0.01	10-12	0915	0.01	10-12	1610	0.01
10-11	2315	0.01	10-12	0925	0.01	10-12	1620	0.01
10-11	2325	0.01	10-12	0935	0.01	10-12	1625	0.01
10-11	2335	0.01	10-12	0945	0.01	10-12	1630	0.01
10-11	2345	0.01	10-12	0955	0.01	10-12	1640	0.01

STORM TOTAL = 1.24

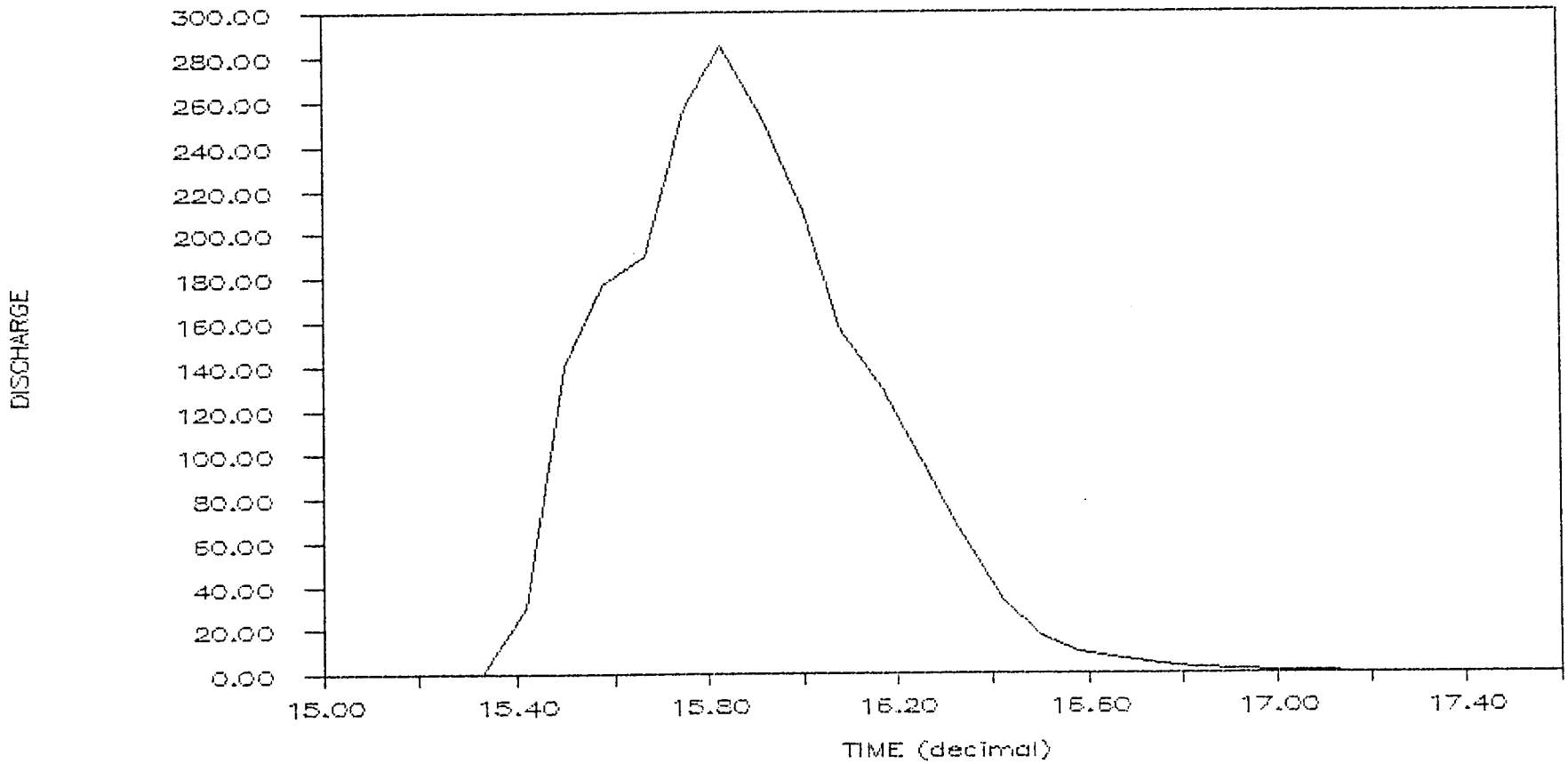
DURATION	5 MIN	15 MIN	30 MIN	1 HR
TIME	1940	1935	1930	1910
DEPTH	0.04	0.08	0.13	0.20
INTENSITY	0.48	0.32	0.26	0.20

145 DCD
388 DBC
345 DG
169 D
102 D

DENVER DATA	DATE	TIME	Q	P1	SUM P1
Concourse D Storm Drain	01-Aug-76	1510	0.00	0.00	0.00
		1515	0.00	0.02	0.02
		1520	0.00	0.12	0.14
		1525	30.00	0.27	0.41
		1530	140.00	0.34	0.75
		1535	177.00	0.21	0.96
		1540	190.00	0.36	1.32
		1545	256.00	0.23	1.55
		1550	285.00	0.20	1.75
		1555	251.00	0.11	1.86
		1600	210.00	0.06	1.92
		1605	156.00	0.03	1.95
		1610	129.00	0.01	1.96
		1615	98.00	0.01	1.97
		1620	66.00	0.00	1.97
		1625	33.00	0.00	1.97
		1630	17.00	0.00	1.97
		1635	9.80	0.00	1.97
		1640	6.70	0.00	1.97
		1645	4.20	0.00	1.97
		1650	2.70	0.00	1.97
		1655	1.80	0.00	1.97
		1700	1.10	0.00	1.97
		1705	0.80	0.00	1.97
		1710	0.50	0.00	1.97
		1715	0.30	0.00	1.97
		1720	0.20	0.00	1.97
		1725	0.10	0.00	1.97
		1730	0.10	0.00	1.97
		1735	0.00	0.00	1.97

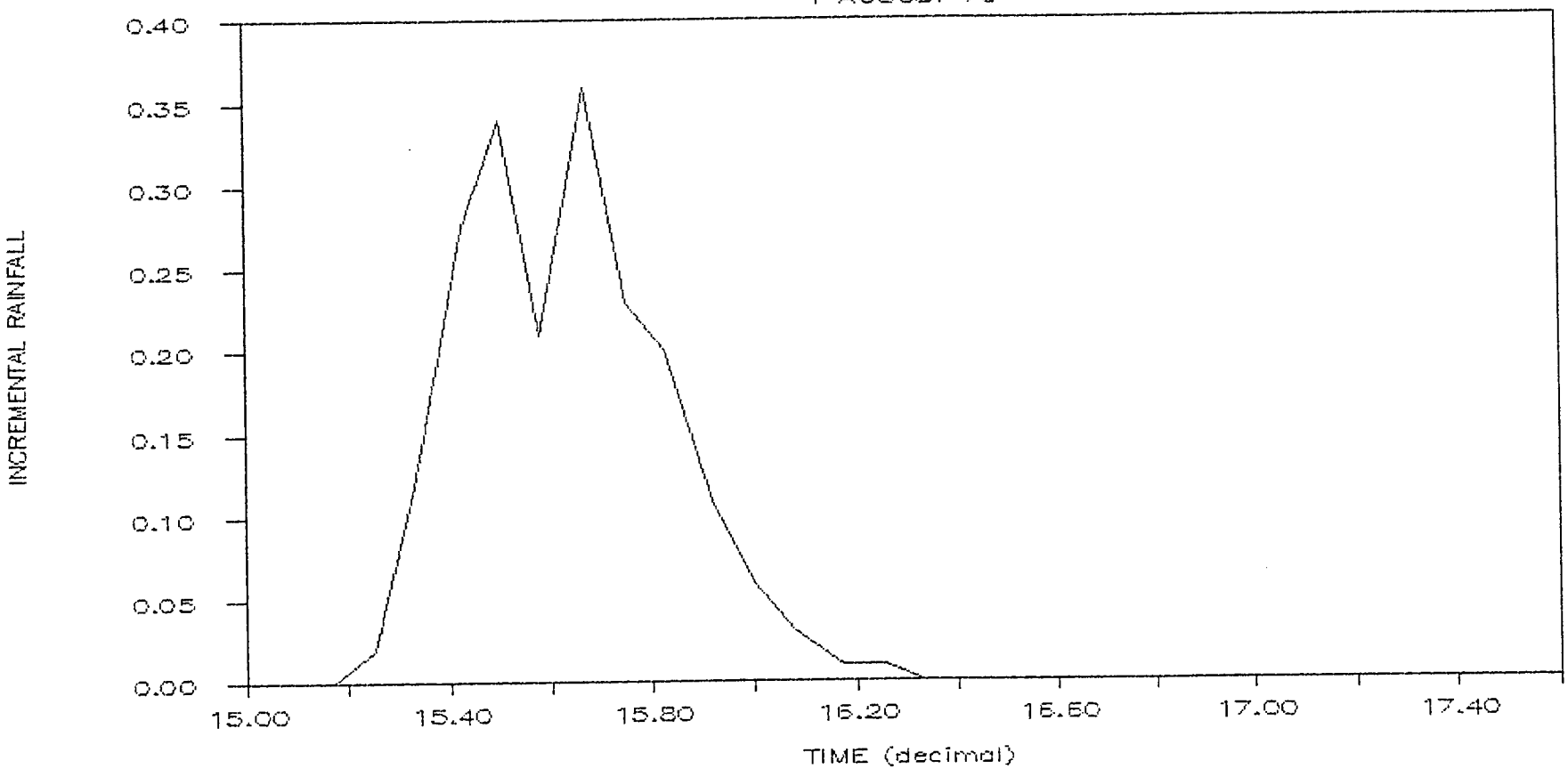
CONCOURSE D STORM DRAIN

1 AUGUST 1976



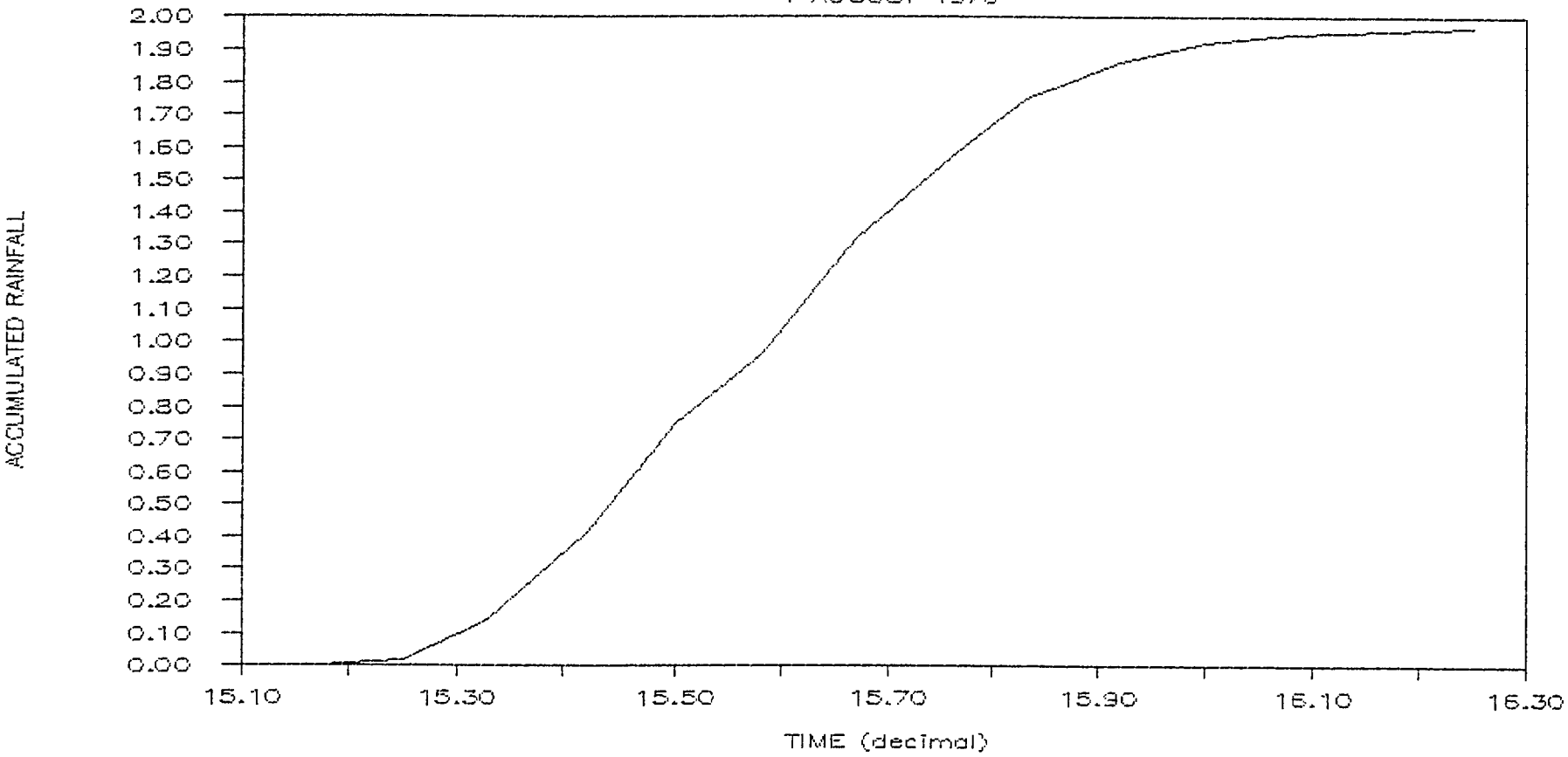
CONCOURSE D STORM DRAIN

1 AUGUST 76

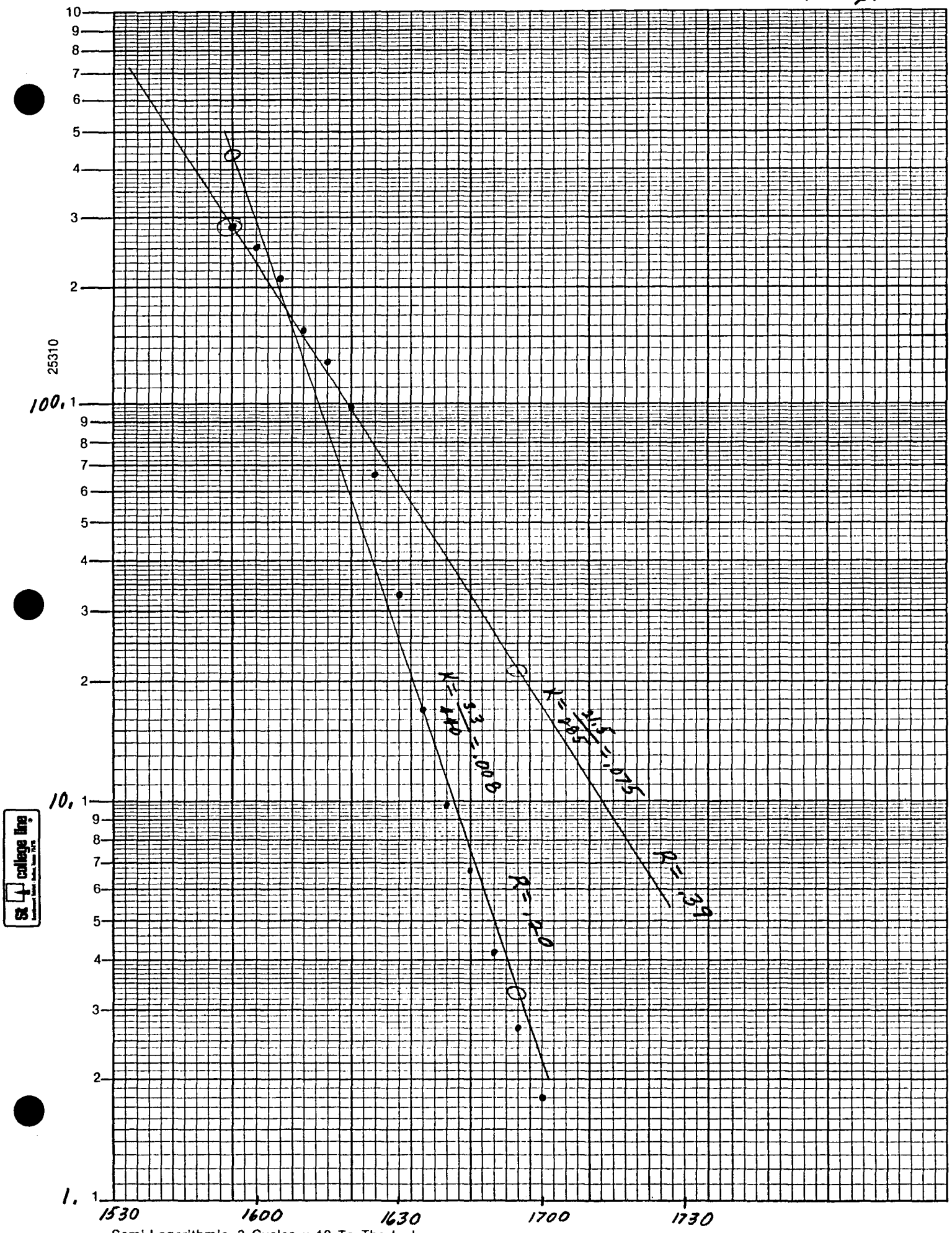


CONCOURSE D STORM DRAIN

1 AUGUST 1976



11 Sept. 87


25310
100.
10.
1.
1530
1600
1630
1700
1730
Semi-Logarithmic 3 Cycles x 10 To The Inch
1 Aug 76
R = .39
R = -.20
K = 3.5/-.075
K = 3.3/-.008

06728400 BOULDER CREEK TRIBUTARY AT BOULDER, COLO.

LOCATION.--Lat 39°58'48", long 105°14'41", in SE¼NE¼ sec.8, T.1 S., R.70 W., Boulder County, on right bank at culvert at State Highway 93 (Broadway) in Boulder, 2,400 ft (730 m) southeast of intersection of Broadway and Table Mesa Dr., and 2,600 ft (790 m) below outlet of Viele Lake.

DRAINAGE AREA.--0.20 mi² (0.52 km²), revised.

PERIOD OF RECORD.--Apr. 23, 1970, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

REMARKS.--Basin drains residential area.

STAGE-DISCHARGE RELATION.--Rating developed on basis of culvert computation and discharge measurement at discharge of 9.0 ft³/s (0.25 m³/s).

EXTREMES.--Water year 1975: Maximum discharge, 13 ft³/s (0.368 m³/s) May 29; no flow most of year.
Water year 1976: Maximum discharge, 80 ft³/s (2.26 m³/s) June 23; no flow most of year.
Water year 1977: Maximum discharge, 24 ft³/s (0.68 m³/s) May 28; no flow most of year.
Period of record: Maximum discharge, 123 ft³/s (3.48 m³/s) June 16, 1972; no flow most of each year.

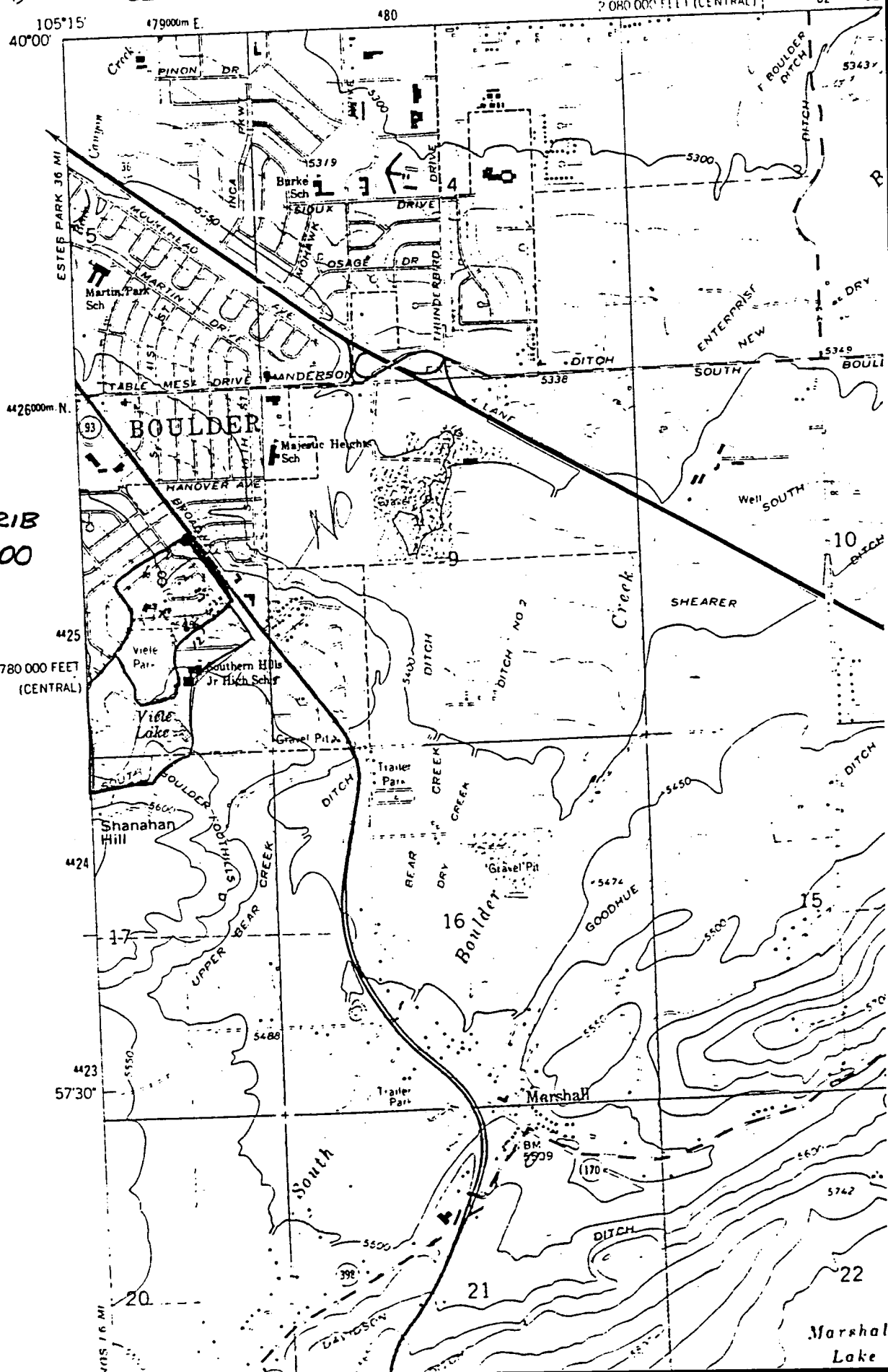
RAINFALL MAY 28-29, 1975

RAINFALL, IN INCHES, DURING INDICATED INTERVAL

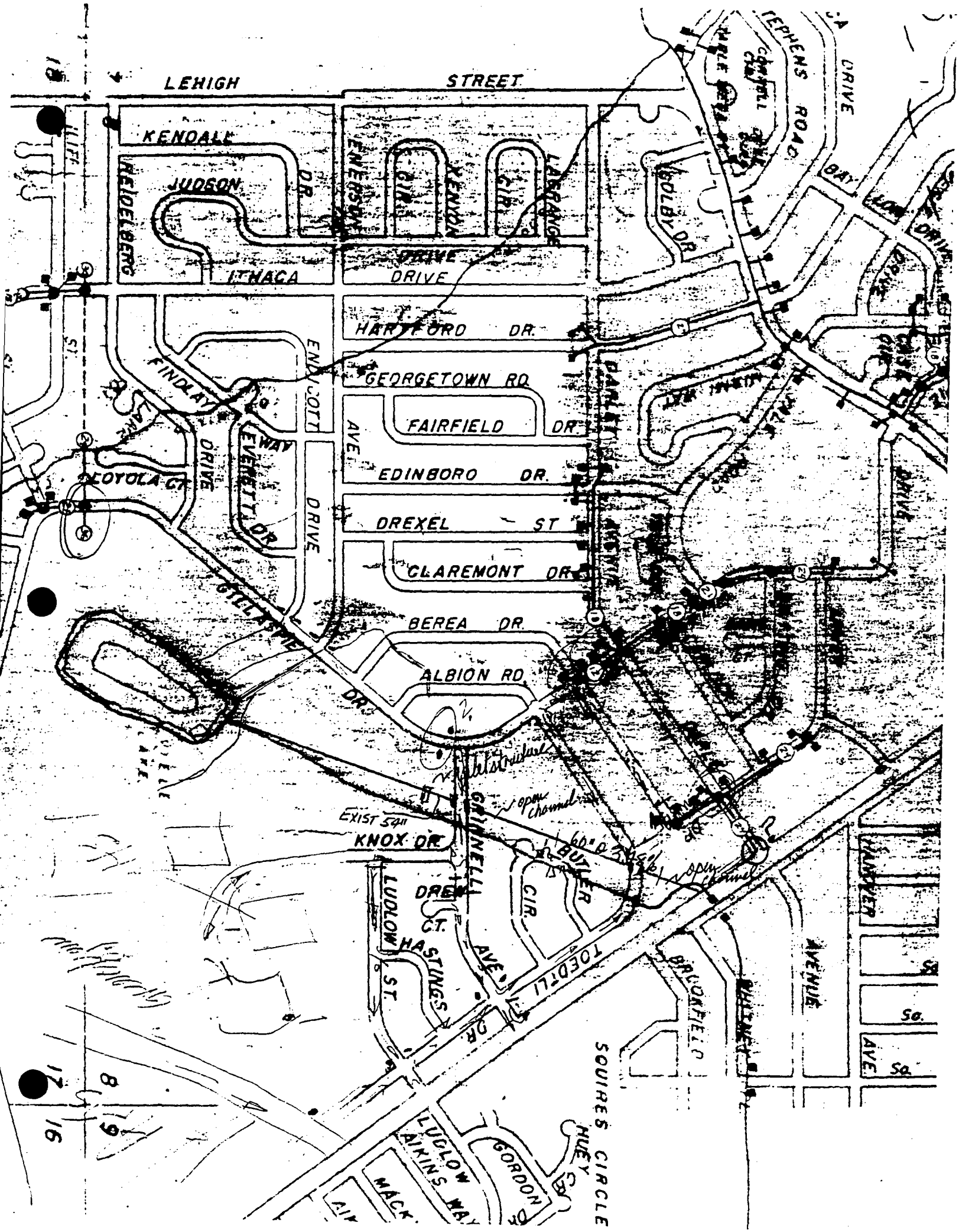
DATE	TIME	RAINFALL	DATE	TIME	RAINFALL	DATE	TIME	RAINFALL
5-28	0750	0.03	5-28	1325	0.01	5-28	1925	0.01
5-28	0755	0.02	5-28	1330	0.01	5-28	1930	0.01
5-28	0805	0.01	5-28	1335	0.01	5-28	1940	0.01
5-28	0815	0.01	5-28	1340	0.01	5-28	1945	0.01
5-28	0825	0.02	5-28	1345	0.01	5-28	1950	0.01
5-28	0830	0.03	5-28	1350	0.01	5-28	1955	0.01
5-28	0835	0.03	5-28	1355	0.01	5-28	2000	0.01
5-28	0840	0.02	5-28	1400	0.01	5-28	2005	0.01
5-28	0845	0.01	5-28	1405	0.01	5-28	2010	0.01
5-28	0855	0.01	5-28	1415	0.01	5-28	2020	0.01
5-28	0900	0.01	5-28	1435	0.01	5-28	2025	0.01
5-28	0905	0.01	5-28	1440	0.01	5-28	2035	0.01
5-28	0915	0.01	5-28	1445	0.02	5-28	2045	0.01
5-28	0930	0.01	5-28	1450	0.01	5-28	2050	0.01
5-28	0945	0.01	5-28	1455	0.01	5-28	2105	0.01
5-28	0950	0.01	5-28	1500	0.01	5-28	2120	0.01
5-28	0955	0.01	5-28	1505	0.01	5-28	2125	0.01
5-28	1000	0.01	5-28	1510	0.01	5-28	2135	0.01
5-28	1005	0.01	5-28	1515	0.01	5-28	2140	0.01
5-28	1010	0.02	5-28	1520	0.01	5-28	2150	0.01
5-28	1015	0.02	5-28	1525	0.01	5-28	2155	0.01
5-28	1020	0.02	5-28	1530	0.02	5-28	2205	0.01
5-28	1025	0.02	5-28	1535	0.01	5-28	2210	0.01
5-28	1030	0.02	5-28	1540	0.01	5-28	2215	0.01
5-28	1035	0.01	5-28	1550	0.01	5-28	2220	0.01
5-28	1040	0.01	5-28	1555	0.01	5-28	2225	0.01
5-28	1045	0.01	5-28	1600	0.01	5-28	2230	0.01
5-28	1050	0.01	5-28	1610	0.01	5-28	2235	0.02
5-28	1100	0.01	5-28	1615	0.01	5-28	2240	0.01
5-28	1105	0.01	5-28	1620	0.01	5-28	2245	0.01
5-28	1110	0.01	5-28	1630	0.02	5-28	2250	0.01
5-28	1115	0.01	5-28	1635	0.02	5-28	2255	0.01
5-28	1120	0.02	5-28	1640	0.01	5-28	2300	0.02
5-28	1125	0.02	5-28	1645	0.02	5-28	2305	0.01
5-28	1130	0.01	5-28	1650	0.01	5-28	2310	0.02
5-28	1135	0.03	5-28	1655	0.01	5-28	2315	0.01
5-28	1140	0.02	5-28	1700	0.01	5-28	2320	0.01
5-28	1145	0.02	5-28	1705	0.01	5-28	2325	0.02
5-28	1150	0.01	5-28	1710	0.01	5-28	2330	0.01
5-28	1155	0.01	5-28	1715	0.01	5-28	2335	0.02
5-28	1205	0.01	5-28	1720	0.01	5-28	2340	0.01
5-28	1215	0.01	5-28	1725	0.01	5-28	2345	0.01
5-28	1225	0.01	5-28	1810	0.01	5-28	2350	0.02
5-28	1230	0.01	5-28	1820	0.01	5-28	2355	0.01
5-28	1240	0.01	5-28	1830	0.01	5-29	2400	0.01
5-28	1250	0.01	5-28	1835	0.01			
5-28	1300	0.01	5-28	1850	0.01			
5-28	1305	0.01	5-28	1900	0.01	5-29	0005	0.01
5-28	1310	0.01	5-28	1910	0.01	5-29	0010	0.02
5-28	1320	0.01	5-28	1915	0.01	5-29	0015	0.01

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LOUISVILLE QUADRANGLE



ER CRK TRIB
06728400


LEHIGH STREET
KENDALE
JUDSON
HEIDELBERG
ITHACA
DR.
EMERSON
GIR.
KENYON
GIR.
LAFRANCE
DRIVE
DRIVE
WOLBY DR.
HARTFORD DR.
GEORGETOWN RD.
FAIRFIELD DR.
EDINBORO DR.
DREXEL ST
CLAREMONT DR.
BEREA DR.
ALBION RD.
ENDICOTT
AVE.
FINDLAY
WAY
EVERETT DR.
DRIVE
LOYOLA CT.
GILLASPIE
DR.
KNOX DR.
EXIST 54"
open channel
GRINNELL
BUTLER
GIR.
LUDLOW
ST.
HASTINGS
DR.
C.T.
AVE.
TOEDTLI
BROOKFIELD
SQUIRES CIRCLE
HUEY
GORDON
LUDLOW
AIKINS WAY
MACK
HANOVER
AVENUE
AVE.
Sa.
STEPHENS ROAD
DRIVE
BAY
DRIVE
PARKLAND
AVENUE
DRIVE
17
8
16

Boulder ck.

area = 48.3 acres $.075 mi^2$

length of main channel = 2,400 ft

imp. area (total) = 11.52 acres 24%

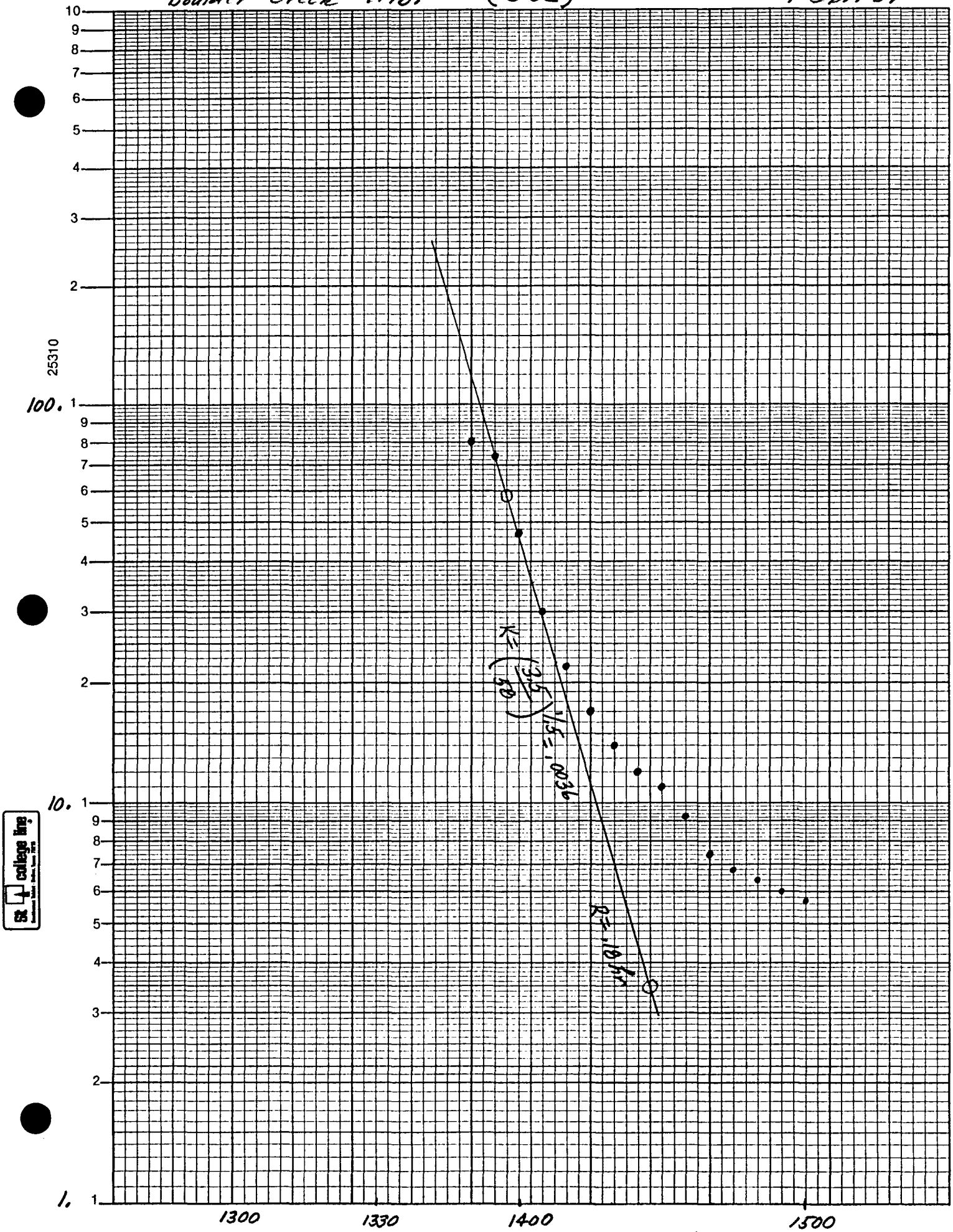
L_{ca} = 1000 ft

slope = $\Sigma L = 1.31$ mi

$\Sigma L/\sqrt{S} = .123$

$$\text{wt'd slope} = \left(\frac{1.31}{.123}\right)^2 = 113.4$$

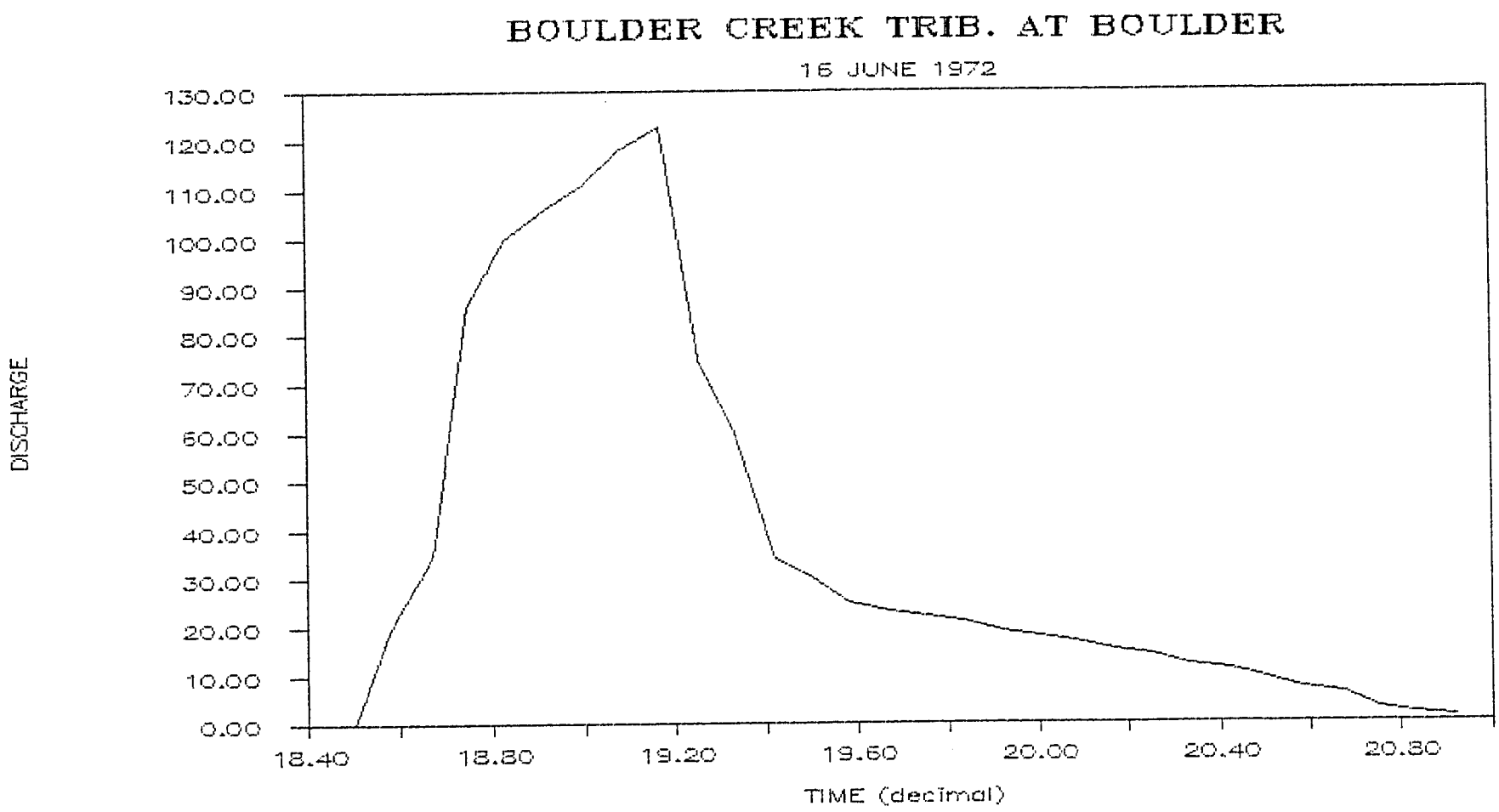
Boulder Creek trib. (DBC) 9 Sept. 87

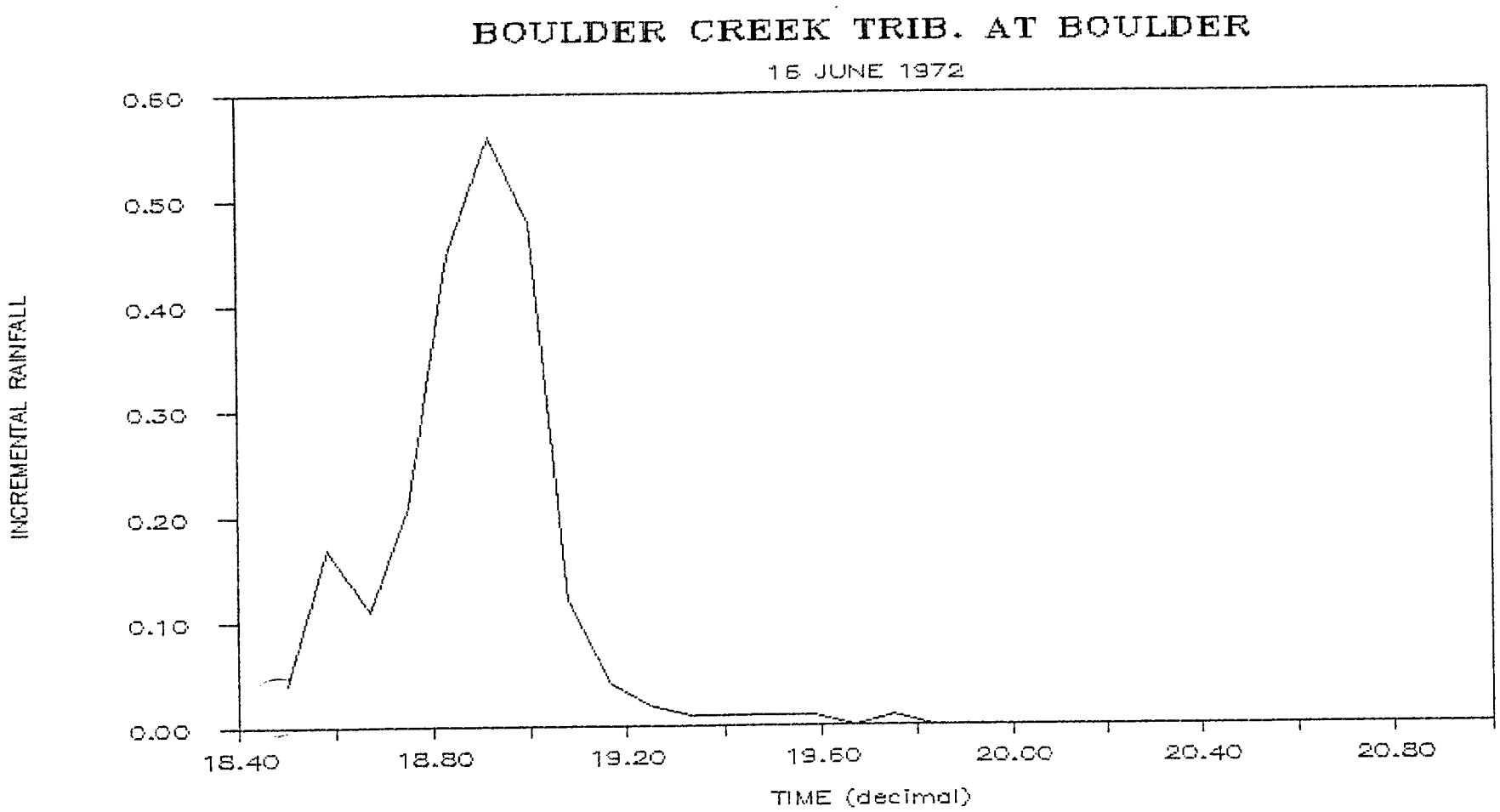


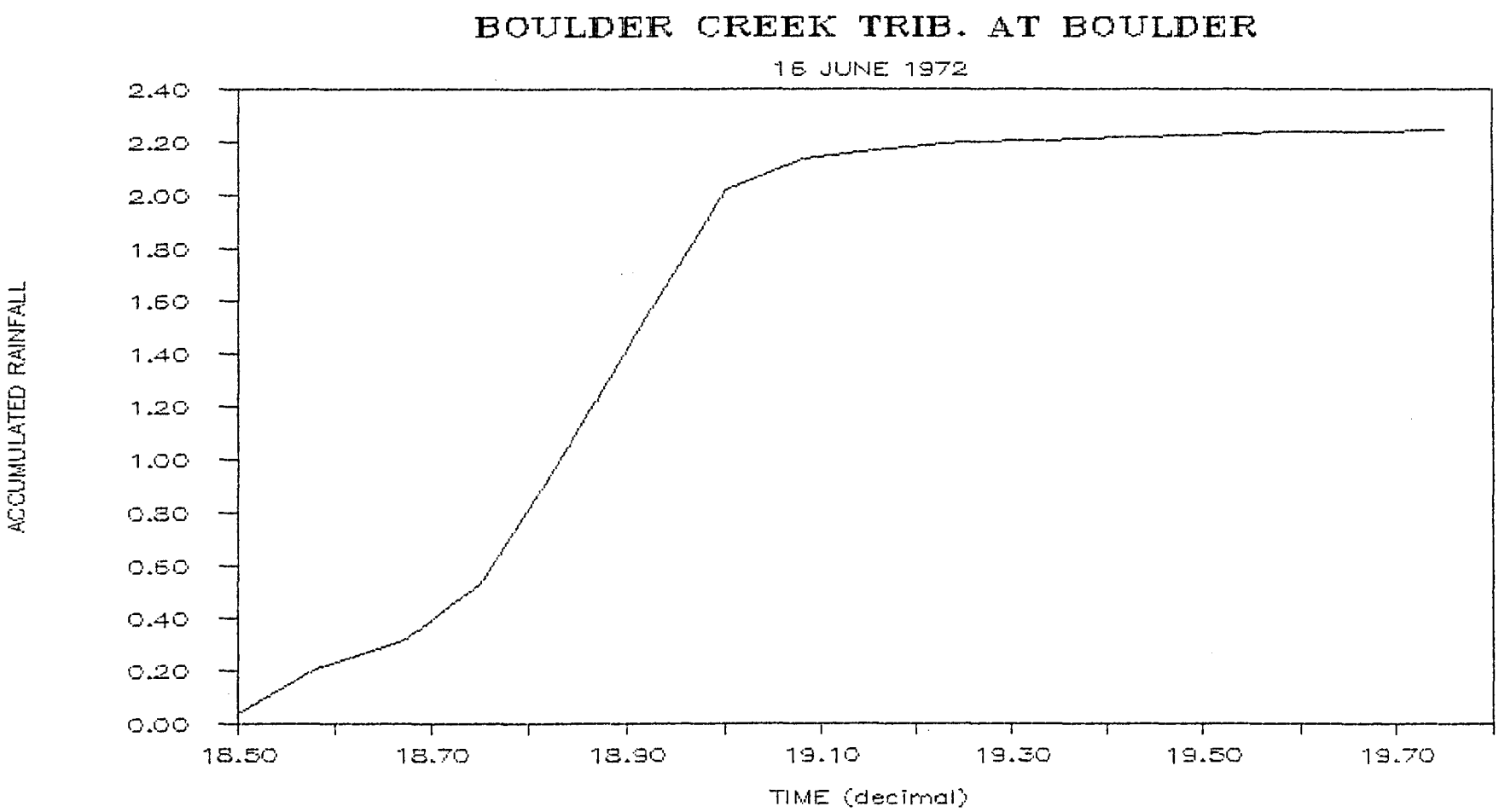
Semi-Logarithmic 3 Cycles x 10 To The Inch

23 Jun 76

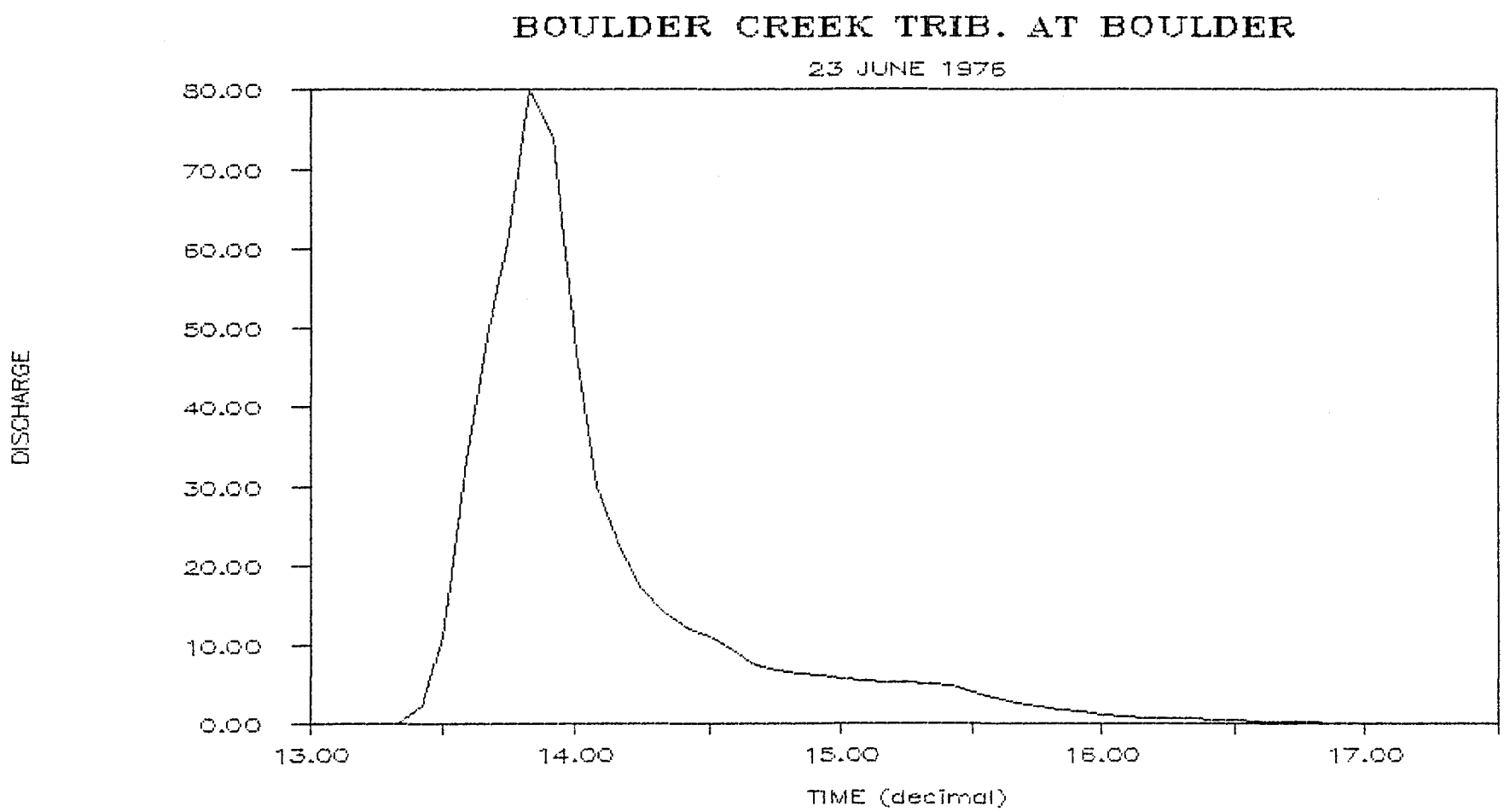
DENVER DATA	DATE	TIME	Q	P1	SUM P1
Boulder Ck. trib. at Boulder	16-Jun-72	1830	0.00	0.04	0.04
		1835	20.00	0.17	0.21
		1840	35.00	0.11	0.32
		1845	86.00	0.21	0.53
		1850	100.00	0.45	0.98
		1855	106.00	0.56	1.54
		1900	111.00	0.48	2.02
		1905	118.00	0.12	2.14
		1910	123.00	0.04	2.18
		1915	75.00	0.02	2.20
		1920	60.00	0.01	2.21
		1925	34.00	0.01	2.22
		1930	30.00	0.01	2.23
		1935	25.00	0.01	2.24
		1940	23.00	0.00	2.24
		1945	22.00	0.01	2.25
		1950	21.00	0.00	2.25
		1955	19.00	0.00	2.25
		2000	18.00	0.00	2.25
		2005	17.00	0.00	2.25
		2010	15.00	0.00	2.25
		2015	14.00	0.00	2.25
		2020	12.00	0.00	2.25
		2025	11.00	0.00	2.25
		2030	9.00	0.00	2.25
		2035	7.00	0.00	2.25
		2040	6.00	0.00	2.25
		2045	3.00	0.00	2.25
		2050	2.00	0.00	2.25
		2055	1.00	0.00	2.25

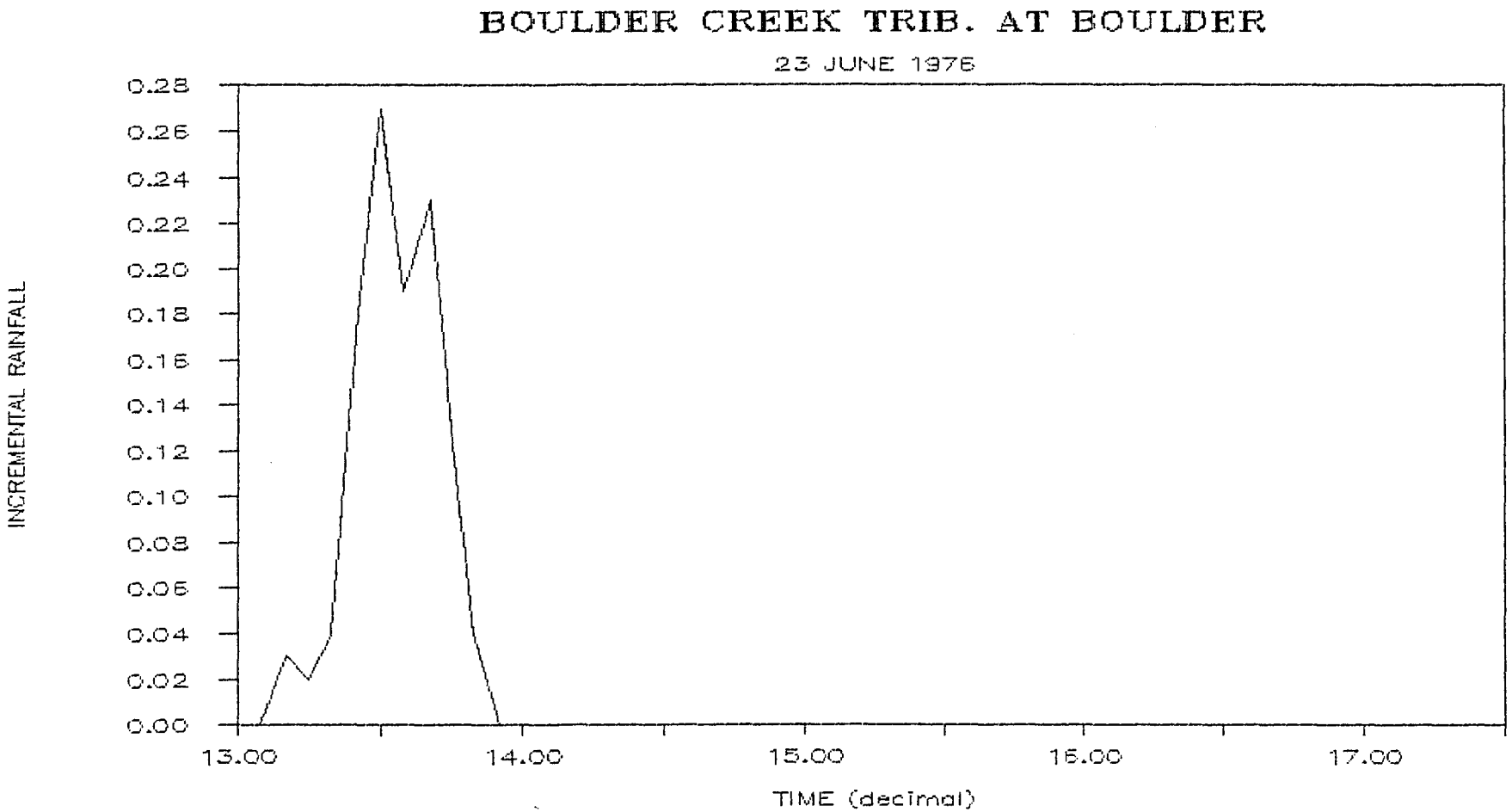

BOULDER CREEK TRIB. AT BOULDER
16 JUNE 1972
DISCHARGE
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
18.40
18.80
19.20
19.60
20.00
20.40
20.80
TIME (decimal)

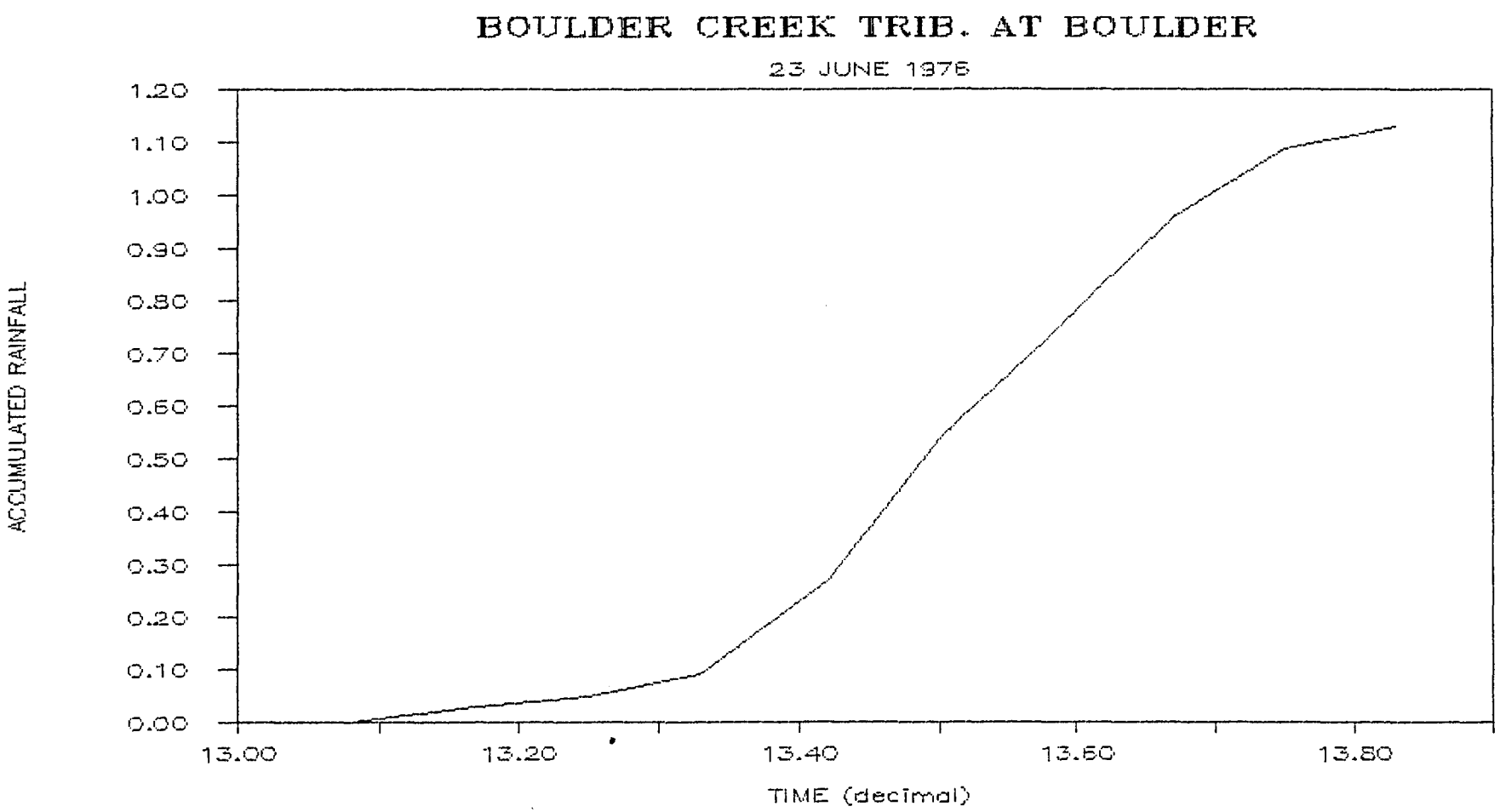

BOULDER CREEK TRIB. AT BOULDER
16 JUNE 1972
INCREMENTAL RAINFALL
0.60
0.50
0.40
0.30
0.20
0.10
0.00
18.40
18.80
19.20
19.60
20.00
20.40
20.80
TIME (decimal)


BOULDER CREEK TRIB. AT BOULDER
16 JUNE 1972
ACCUMULATED RAINFALL
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
18.50
18.70
18.90
19.10
19.30
19.50
19.70
TIME (decimal)

DENVER DATA	DATE	TIME	Q	P1	SUM P1
Boulder Ck. trib. at Boulder	23-Jun-76	1305	0.00	0.00	0.00
		1310	0.00	0.03	0.03
		1315	0.00	0.02	0.05
		1320	0.00	0.04	0.09
		1325	2.20	0.18	0.27
		1330	11.00	0.27	0.54
		1335	32.00	0.19	0.73
		1340	49.00	0.23	0.96
		1345	62.00	0.13	1.09
		1350	80.00	0.04	1.13
		1355	74.00	0.00	1.13
		1400	47.00	0.00	1.13
		1405	30.00	0.00	1.13
		1410	22.00	0.00	1.13
		1415	17.00	0.00	1.13
		1420	14.00	0.00	1.13
		1425	12.00	0.00	1.13
		1430	11.00	0.00	1.13
		1435	9.30	0.00	1.13
		1440	7.40	0.00	1.13
		1445	6.80	0.00	1.13
		1450	6.40	0.00	1.13
		1455	6.00	0.00	1.13
		1500	5.70	0.00	1.13
		1505	5.40	0.00	1.13
		1510	5.30	0.00	1.13
		1515	5.20	0.00	1.13
		1520	4.90	0.00	1.13
		1525	4.80	0.00	1.13
		1530	4.00	0.00	1.13
		1535	3.30	0.00	1.13
		1540	2.60	0.00	1.13
		1545	2.20	0.00	1.13
		1550	1.80	0.00	1.13
		1555	1.50	0.00	1.13
		1600	1.20	0.00	1.13
		1605	1.00	0.00	1.13
		1610	0.80	0.00	1.13
		1615	0.70	0.00	1.13
		1620	0.60	0.00	1.13
		1625	0.50	0.00	1.13
		1630	0.40	0.00	1.13
		1635	0.30	0.00	1.13
		1640	0.30	0.00	1.13
		1645	0.20	0.00	1.13
		1650	0.20	0.00	1.13
		1655	0.10	0.00	1.13
		1660	0.10	0.00	1.13
		1665	0.10	0.00	1.13


BOULDER CREEK TRIB. AT BOULDER
23 JUNE 1976
DISCHARGE
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
13.00
14.00
15.00
16.00
17.00
TIME (decimal)


BOULDER CREEK TRIB. AT BOULDER
23 JUNE 1976
INCREMENTAL RAINFALL
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
13.00
14.00
15.00
16.00
17.00
TIME (decimal)


BOULDER CREEK TRIB. AT BOULDER
23 JUNE 1976
ACCUMULATED RAINFALL
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
13.00
13.20
13.40
13.60
13.80
TIME (decimal)

PLATTE RIVER BASIN

06711700 DRY GULCH AT LAKEWOOD, COLO.

LOCATION.--Lat 39°44'29", long 105°06'43", in SE¼SE¼ sec.33, T.3 S., R.69 W., Jefferson County, on left bank 800 ft (240 km) upstream from storm drain at Kipling St., and 500 ft (150 km) east of intersection of Miller St. and W. 15th Pl. in Lakewood.

DRAINAGE AREA.--0.58 mi^2 (1.50 km^2).

PERIOD OF RECORD.--May 6, 1971, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

STAGE-DISCHARGE RELATION.--Rating developed on basis of step-backwater analysis of reach of natural stream channel and discharge measurement at gage height 11.48 ft (3.499 m).

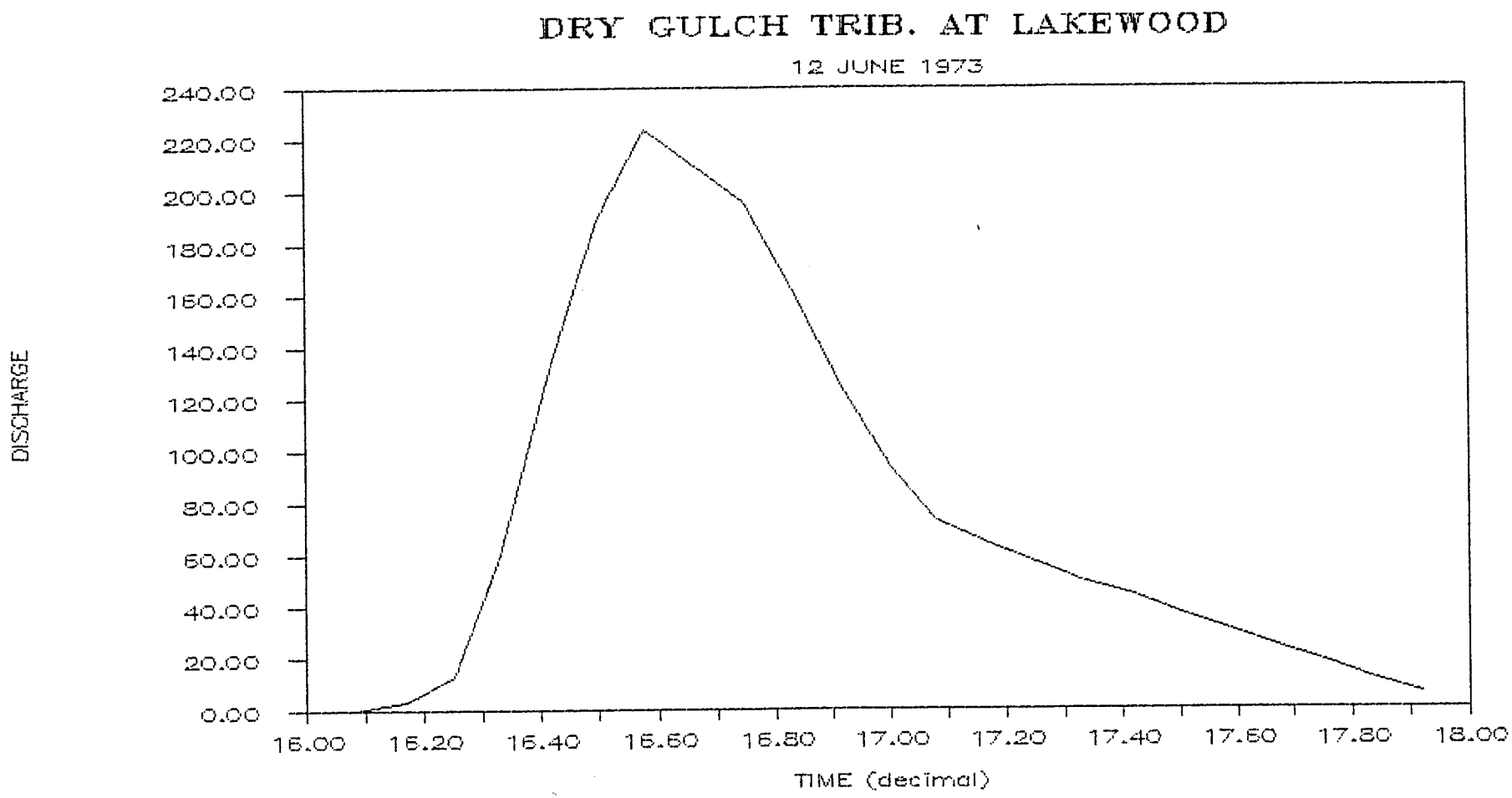
EXTREMES.--Water year 1972: Maximum discharge, 69 ft^3/s (1.95 m^3/s) Sept. 7 (gage height, 13.10 ft or 3.993 m); very little flow most of year.
Water year 1973: Maximum discharge, 224 ft^3/s (6.34 m^3/s) June 12 (gage height, 15.84 ft or 4.828 m); very little flow most of year.
Water year 1974: Maximum discharge, 48 ft^3/s (1.36 m^3/s) June 6 (gage height, 12.57 ft or 3.831 m); very little flow most of year.
Period of record: Maximum discharge, 224 ft^3/s (6.34 m^3/s) June 12, 1973 (gage height, 15.84 ft or 4.828 m); very little flow most of each year.

REMARKS.--Basin drains shopping center complex and residential area.

RAINFALL, IN INCHES, MAY 6, 1972

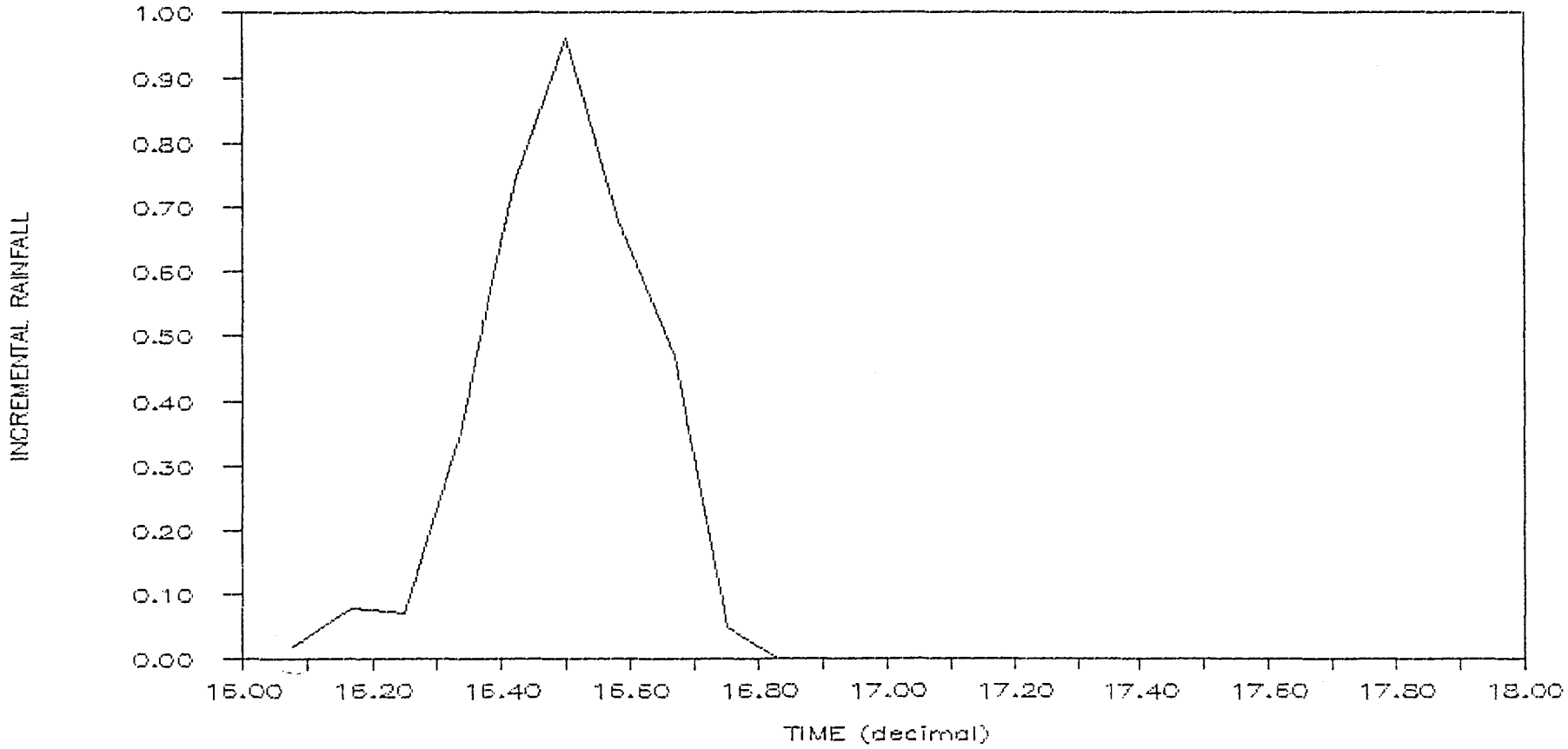
DATE	TIME	INTERVAL DEPTH	ACCUMULATED DEPTH	DAILY TOTAL	MIDNIGHT DIAL
					5.01 (FIRST READING ON TAPE)
05-06	0100				
05-06	0405	0.03	0.03		
05-06	0410	0.03	0.06		
05-06	0415	0.03	0.09		
05-06	0420	0.01	0.10		
05-06	0425	0.01	0.11		
05-06	0430	0.01	0.12		
05-06	0445	0.01	0.13		
05-06	0535	0.01	0.14		
05-06	0550	0.01	0.15		
05-06	0605	0.01	0.16		
05-06	0615	0.01	0.17		
05-06	0620	0.02	0.19		
05-06	0625	0.02	0.21		
05-06	0630	0.02	0.23		
05-06	0635	0.02	0.25		
05-06	0640	0.04	0.29		
05-06	0645	0.02	0.31		
05-06	0650	0.02	0.33		
05-06	0655	0.02	0.35		
05-06	0700	0.02	0.37		
05-06	0705	0.02	0.39		
05-06	0710	0.03	0.42		
05-06	0715	0.03	0.45		
05-06	0720	0.02	0.47		
05-06	0725	0.02	0.49		
05-06	0730	0.02	0.51		
05-06	0735	0.02	0.53		
05-06	0740	0.03	0.56		
05-06	0745	0.03	0.59		
05-06	0750	0.01	0.60		
05-06	0755	0.01	0.61		
05-06	0800	0.01	0.62		
05-06	0810	0.01	0.63		
05-06	0815	0.01	0.64		
05-06	0825	0.01	0.65		
05-06	0835	0.01	0.66		
05-06	0840	0.01	0.67		
05-06	0850	0.01	0.68		
05-06	0920	0.01	0.69		
05-06	0935	0.01	0.70		
05-06	1000	0.01	0.71		
05-06	1015	0.01	0.72		
05-06	1030	0.01	0.73		
05-06	1035	0.01	0.74		
05-06	1040	0.01	0.75		

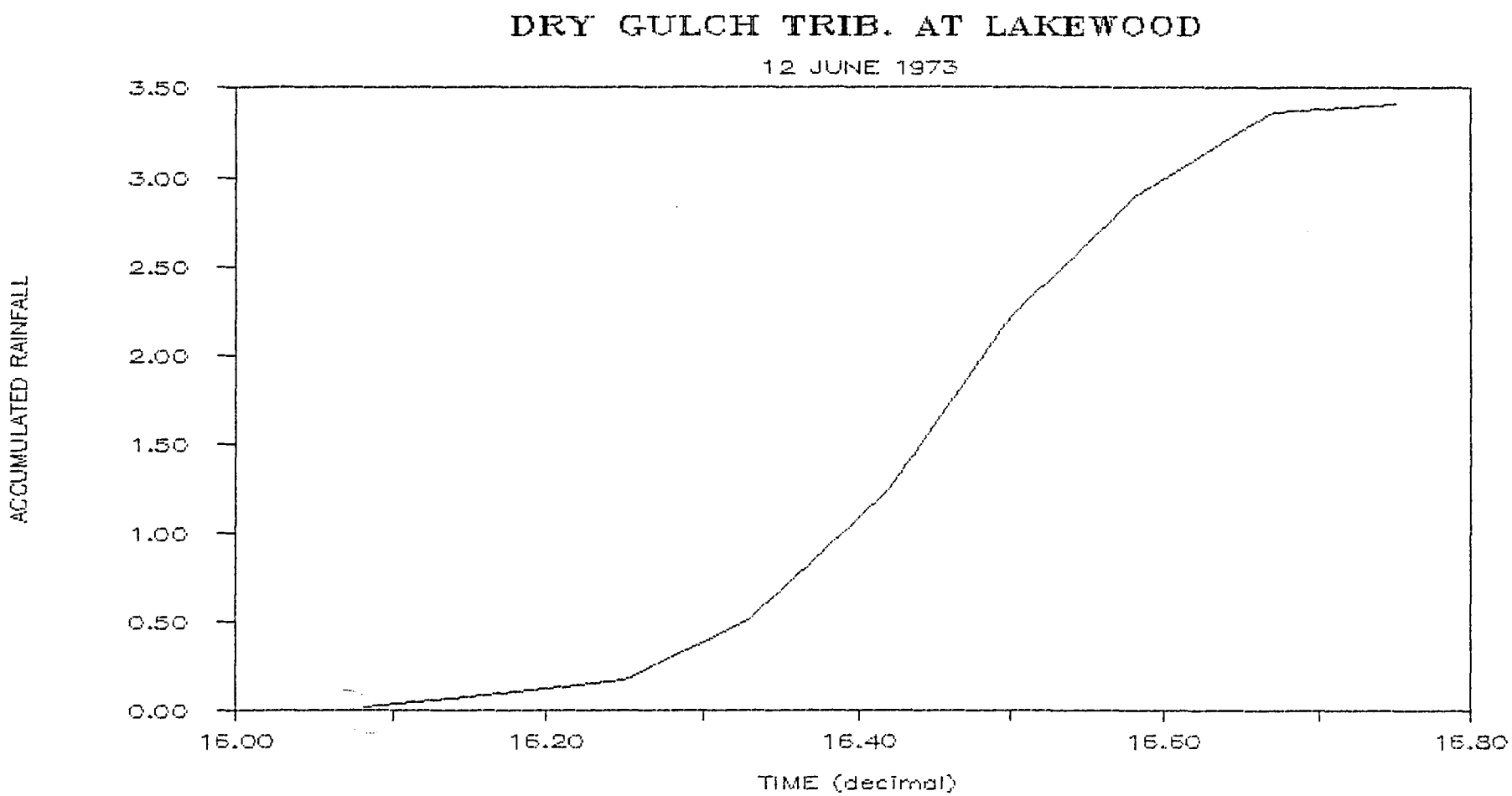
DENVER DATA	DATE	TIME	Q	P1	SUM P1
Dry Gulch Trib at Lakewood	12-Jun-73	1605	0.00	0.02	0.02
		1610	3.30	0.08	0.10
		1615	13.00	0.07	0.17
		1620	61.00	0.34	0.51
		1625	134.00	0.74	1.25
		1630	190.00	0.96	2.21
		1635	224.00	0.68	2.89
		1640	209.00	0.47	3.36
		1645	196.00	0.05	3.41
		1650	162.00	0.00	3.41
		1655	122.00	0.00	3.41
		1700	94.00	0.00	3.41
		1705	73.00	0.00	3.41
		1710	64.00	0.00	3.41
		1715	57.00	0.00	3.41
		1720	50.00	0.00	3.41
		1725	44.00	0.00	3.41
		1730	37.00	0.00	3.41
		1735	31.00	0.00	3.41
		1740	24.00	0.00	3.41
		1745	18.00	0.00	3.41
		1750	12.00	0.00	3.41
		1755	6.00	0.00	3.41
		1800	0.0	0.0	3.41


DRY GULCH TRIB. AT LAKEWOOD
12 JUNE 1973
DISCHARGE
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
16.00
16.20
16.40
16.60
16.80
17.00
17.20
17.40
17.60
17.80
18.00
TIME (decimal)

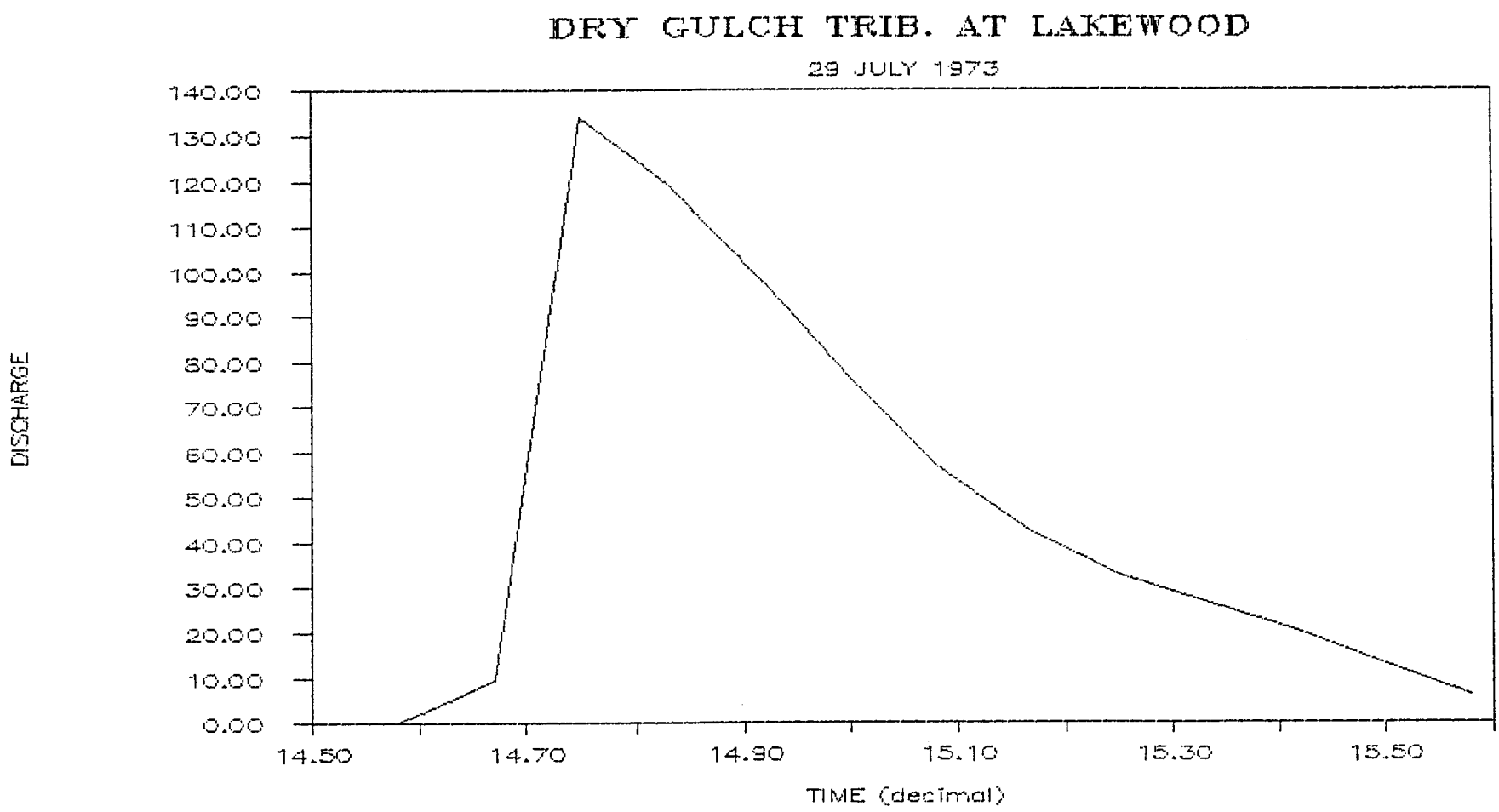
DRY GULCH TRIB. AT LAKEWOOD

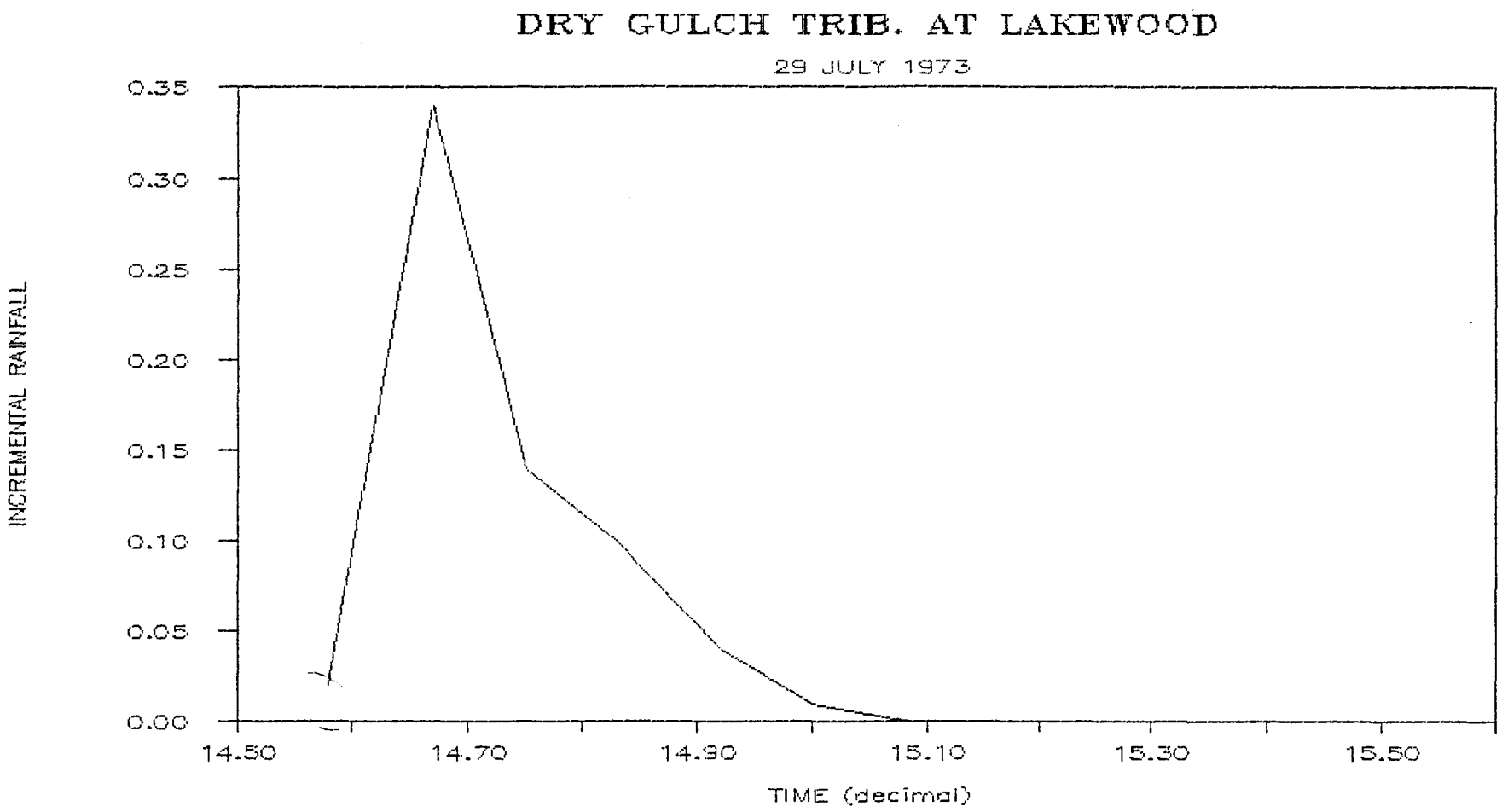
12 JUNE 1973

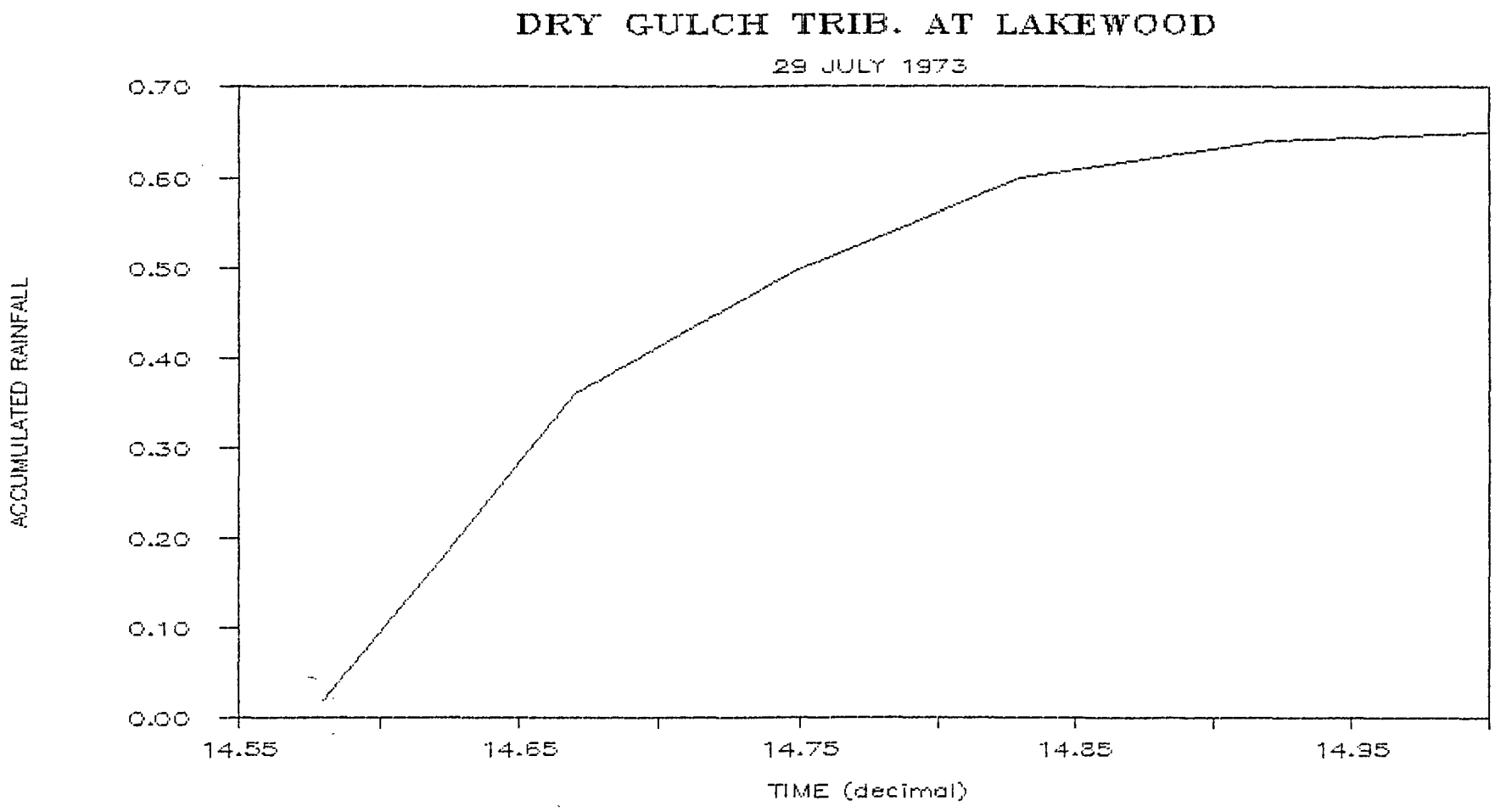



DRY GULCH TRIB. AT LAKEWOOD
12 JUNE 1973
ACCUMULATED RAINFALL
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
16.00
16.20
16.40
16.60
16.80
TIME (decimal)

DENVER DATA	DATE	TIME	Q	P1	SUM P1
Dry Gulch Trib at Lakewood	29-Jul-73	1435	0.00	0.02	0.02
		1440	9.60	0.34	0.36
		1445	134.00	0.14	0.50
		1450	119.00	0.10	0.60
		1455	97.00	0.04	0.64
		1500	76.00	0.01	0.65
		1505	57.00	0.00	0.65
		1510	42.00	0.00	0.65
		1515	33.00	0.00	0.65
		1520	27.00	0.00	0.65
		1525	20.00	0.00	0.65
		1530	13.00	0.00	0.65
		1535	6.00	0.00	0.65
		1540	[illegible]	[illegible]	0.65


DRY GULCH TRIB. AT LAKEWOOD
29 JULY 1973
DISCHARGE
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
14.50
14.70
14.90
15.10
15.30
15.50
TIME (decimal)


DRY GULCH TRIB. AT LAKEWOOD
29 JULY 1973
INCREMENTAL RAINFALL
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
14.50
14.70
14.90
15.10
15.30
15.50
TIME (decimal)


DRY GULCH TRIB. AT LAKEWOOD
29 JULY 1973
ACCUMULATED RAINFALL
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
14.55
14.65
14.75
14.85
14.95
TIME (decimal)

06714210 SOUTH PLATTE RIVER TRIBUTARY AT DENVER, COLO.

LOCATION.--Lat 39°47'18", long 104°56'32", in NE¼SE¼ sec.13, T.3 S., R.68 W., Denver County, on left bank 350 ft (110 m) north of intersection of Jackson St. and E. 50th Ave., and 3,000 ft (910 m) northwest of intersection of Interstate Highway 70 and Colorado Blvd., in Denver.

DRAINAGE AREA.--0.75 mi^2 (1.86 km^2), revised.

PERIOD OF RECORD.--Apr. 15, 1971, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

REMARKS.--Basin drains industrial area.

STAGE-DISCHARGE RELATION.--Rating developed on basis of characteristics of a standard Parshall flume, an indirect measurement at discharge of 86 ft^3/s (2.44 m^3/s), and discharge measurements at discharges of 3.2 ft^3/s (0.091 m^3/s) and 54 ft^3/s (1.53 m^3/s).

EXTREMES.--Water year 1975: Maximum discharge, 94 ft^3/s (2.66 m^3/s) May 22; no flow most of year.
Water year 1976: Maximum discharge, 61 ft^3/s (1.73 m^3/s) Aug. 1; no flow most of year.
Water year 1977: Maximum discharge, 76 ft^3/s (2.15 m^3/s) May 7; no flow most of year.
Period of record: Maximum discharge, 105 ft^3/s (2.97 m^3/s) July 19, 1973; no flow most of each year.

RAINFALL OCT. 1- 2,1974

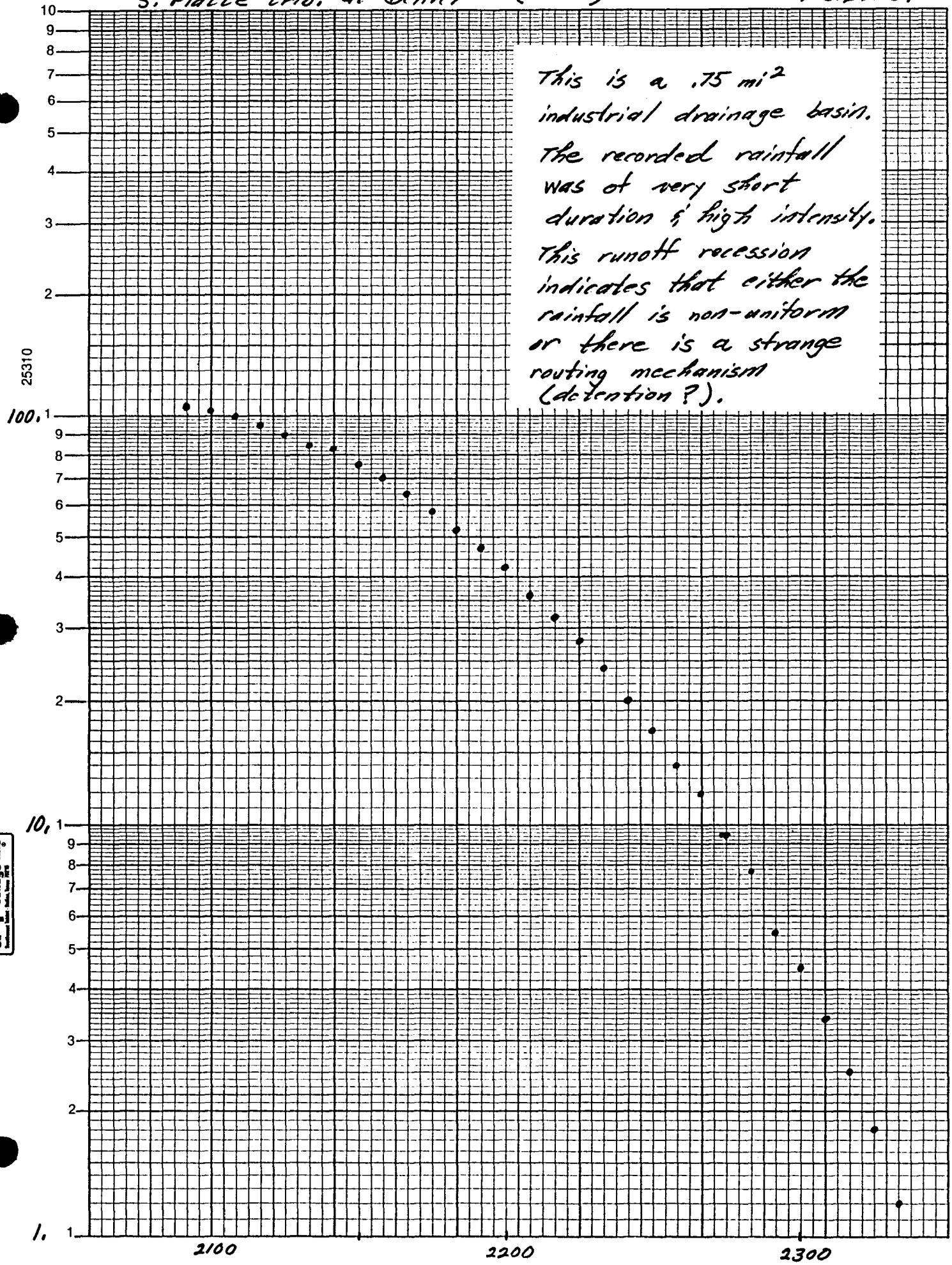
RAINFALL, IN INCHES, DURING INDICATED INTERVAL

DATE	TIME	RAINFALL	DATE	TIME	RAINFALL	DATE	TIME	RAINFALL
10-01	1755	0.02				10-02	1040	0.01
10-01	1805	0.02				10-02	1050	0.01
10-01	1815	0.01	10-02	0005	0.01	10-02	1055	0.01
10-01	1830	0.01	10-02	0025	0.01	10-02	1100	0.01
10-01	1910	0.01	10-02	0035	0.01	10-02	1110	0.01
10-01	1925	0.01	10-02	0055	0.01	10-02	1120	0.01
10-01	1930	0.01	10-02	0110	0.01	10-02	1130	0.01
10-01	1935	0.01	10-02	0125	0.01	10-02	1140	0.01
10-01	1940	0.01	10-02	0155	0.01	10-02	1155	0.01
10-01	1950	0.01	10-02	0305	0.01	10-02	1210	0.01
10-01	2000	0.01	10-02	0340	0.01	10-02	1230	0.01
10-01	2005	0.01	10-02	0445	0.01	10-02	1245	0.01
10-01	2010	0.01	10-02	0545	0.01	10-02	1305	0.01
10-01	2015	0.01	10-02	0610	0.01	10-02	1325	0.01
10-01	2020	0.01	10-02	0625	0.01	10-02	1350	0.01
10-01	2025	0.01	10-02	0640	0.01	10-02	1415	0.01
10-01	2030	0.01	10-02	0655	0.01	10-02	1425	0.01
10-01	2035	0.01	10-02	0710	0.01	10-02	1450	0.01
10-01	2045	0.01	10-02	0730	0.01	10-02	1500	0.01
10-01	2110	0.01	10-02	0740	0.01	10-02	1505	0.01
10-01	2120	0.01	10-02	0750	0.01	10-02	1510	0.01
10-01	2125	0.01	10-02	0800	0.01	10-02	1520	0.01
10-01	2135	0.01	10-02	0815	0.01	10-02	1525	0.01
10-01	2140	0.01	10-02	0825	0.01	10-02	1530	0.01
10-01	2145	0.01	10-02	0830	0.01	10-02	1535	0.01
10-01	2150	0.01	10-02	0835	0.01	10-02	1540	0.01
10-01	2155	0.01	10-02	0845	0.01	10-02	1550	0.01
10-01	2205	0.01	10-02	0855	0.01	10-02	1600	0.01
10-01	2215	0.01	10-02	0900	0.01	10-02	1605	0.01
10-01	2225	0.01	10-02	0910	0.01	10-02	1610	0.01
10-01	2240	0.01	10-02	0920	0.01	10-02	1615	0.01
10-01	2300	0.01	10-02	0930	0.01	10-02	1620	0.01
10-01	2315	0.01	10-02	0935	0.01	10-02	1630	0.01
10-01	2325	0.01	10-02	0950	0.01	10-02	1640	0.01
10-01	2335	0.01	10-02	1000	0.01	10-02	1650	0.01
10-01	2350	0.01	10-02	1010	0.01	10-02	1705	0.01
			10-02	1025	0.01			
			10-02	1035	0.01			

STORM TOTAL = 1.10

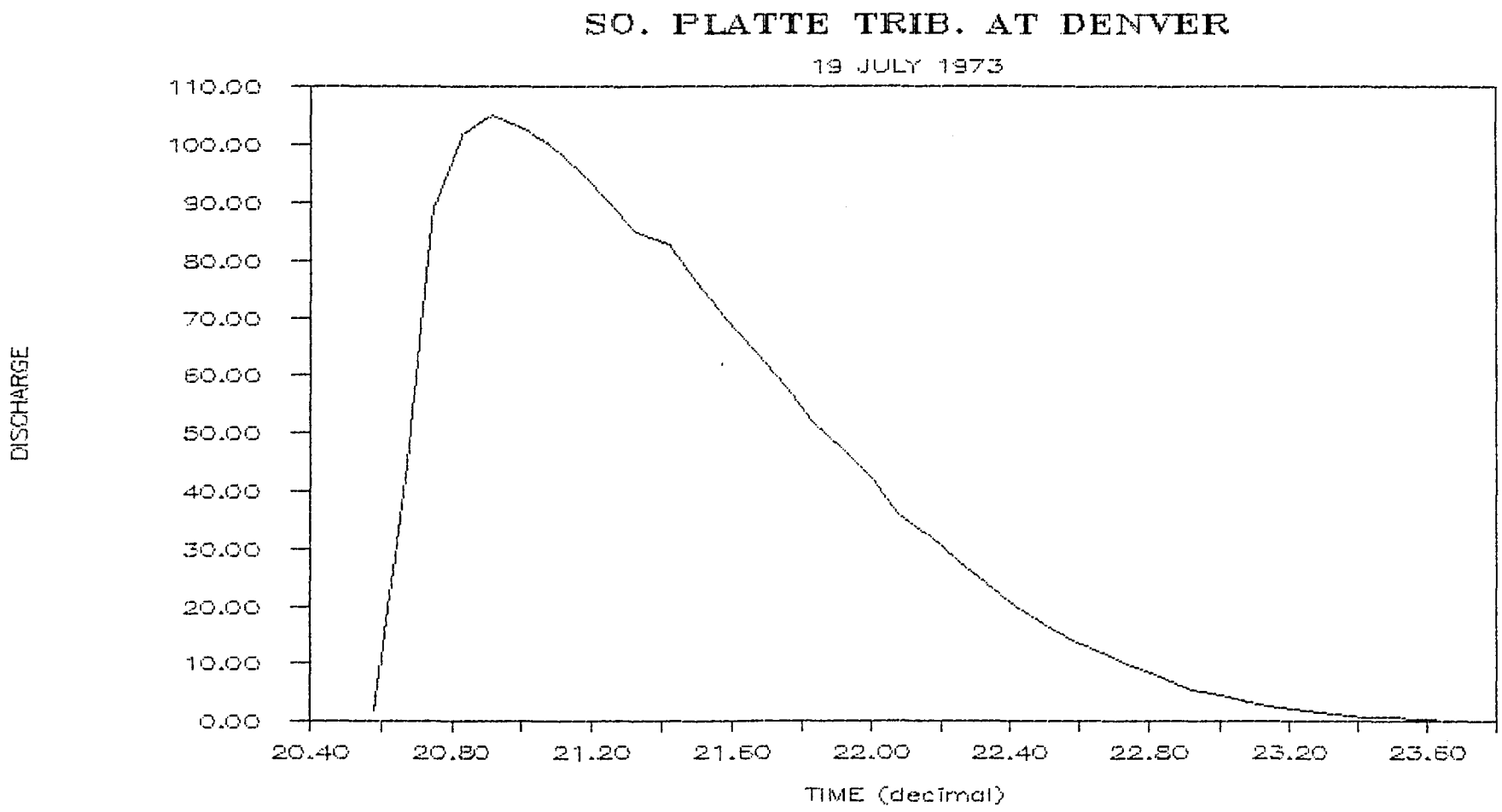
DURATION	5 MIN	15 MIN	30 MIN	1 HR
TIME	1750	1750	1955	1920
DEPTH	0.02	0.04	0.06	0.10
INTENSITY	0.24	0.16	0.12	0.10

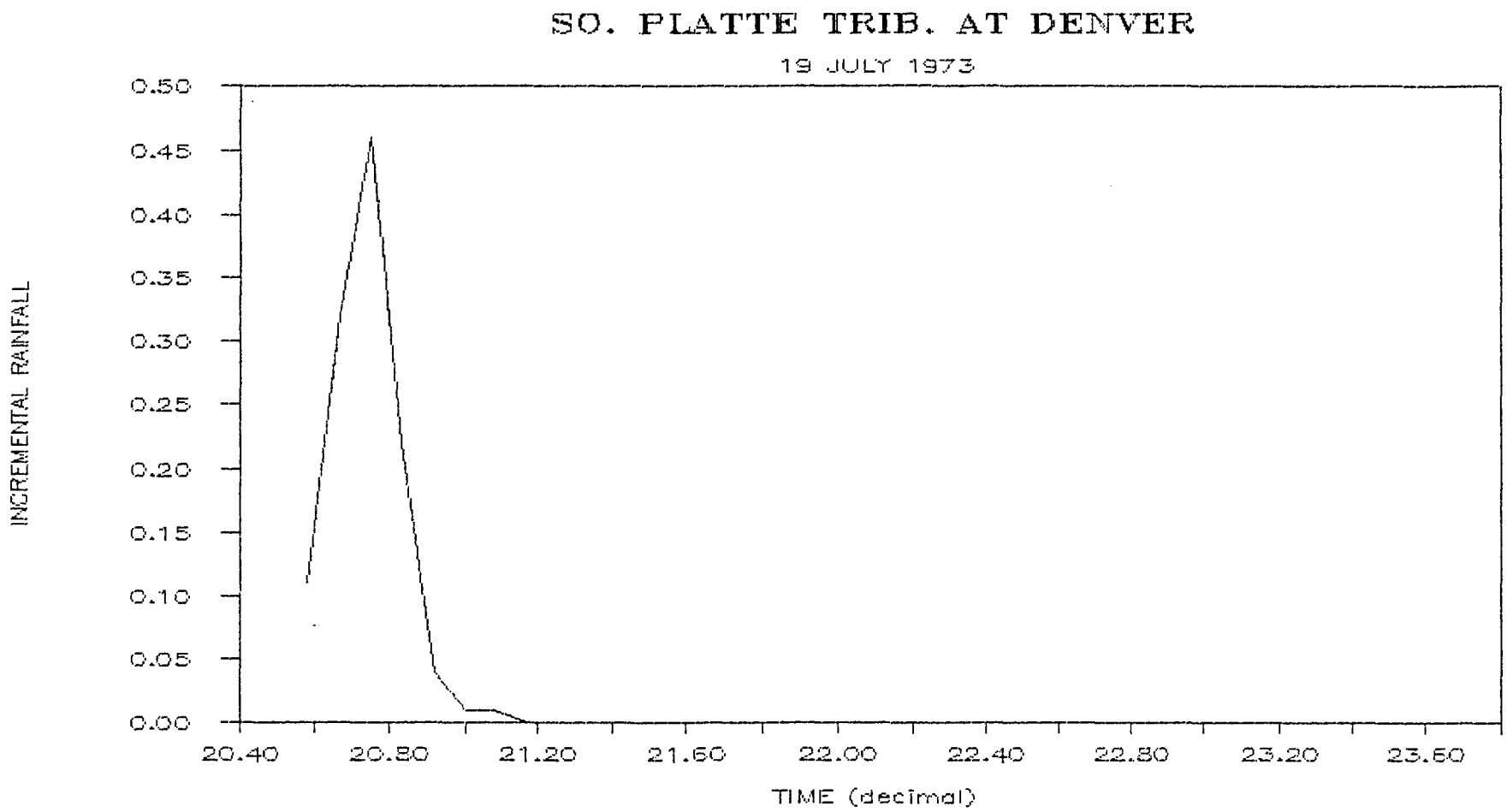
S. Platte trib. at Denver (DSP) 9 Sept. 87

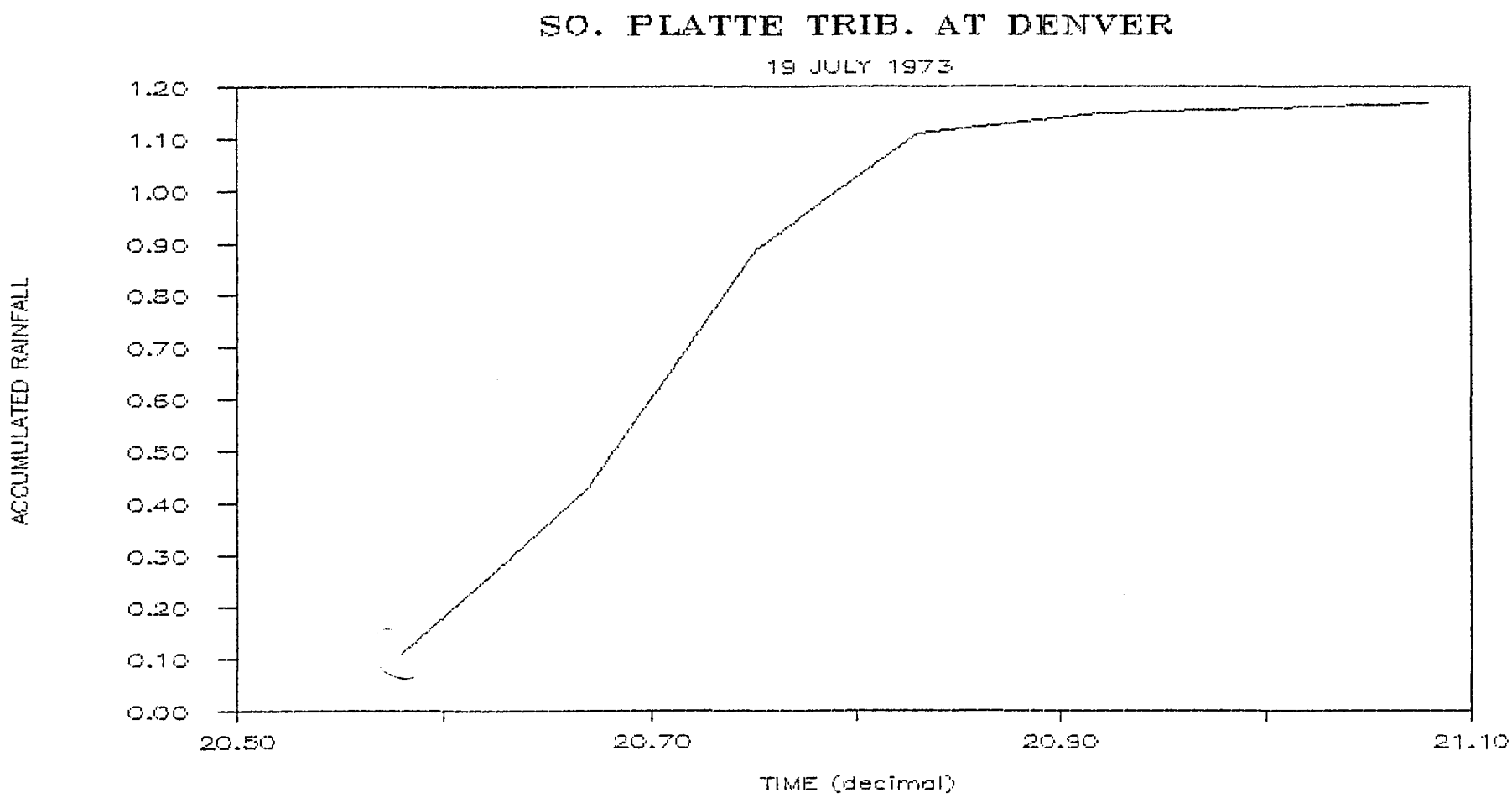


Semi-Logarithmic 3 Cycles x 10 To The Inch

DENVER DATA	DATE	TIME	Q	P1	SUM P1
So. Platte trib. at Denver	19-Jul-73	2035	1.80	0.11	0.11
		2040	42.00	0.32	0.43
		2045	89.00	0.46	0.89
		2050	102.00	0.22	1.11
		2055	105.00	0.04	1.15
		2100	103.00	0.01	1.16
		2105	100.00	0.01	1.17
		2110	95.00	0.00	1.17
		2115	90.00	0.00	1.17
		2120	85.00	0.00	1.17
		2125	83.00	0.00	1.17
		2130	76.00	0.00	1.17
		2135	70.00	0.00	1.17
		2140	64.00	0.00	1.17
		2145	58.00	0.00	1.17
		2150	52.00	0.00	1.17
		2155	47.00	0.00	1.17
		2200	42.00	0.00	1.17
		2205	36.00	0.00	1.17
		2210	32.00	0.00	1.17
		2215	28.00	0.00	1.17
		2220	24.00	0.00	1.17
		2225	20.00	0.00	1.17
		2230	17.00	0.00	1.17
		2235	14.00	0.00	1.17
		2240	12.00	0.00	1.17
		2245	9.50	0.00	1.17
		2250	7.70	0.00	1.17
		2255	5.50	0.00	1.17
		2300	4.50	0.00	1.17
		2305	3.40	0.00	1.17
		2310	2.50	0.00	1.17
		2315	1.80	0.00	1.17
		2320	1.20	0.00	1.17
		2325	0.80	0.00	1.17
		2330	0.60	0.00	1.17
		2335	0.40	0.00	1.17
		2340	0.20	0.00	1.17
		2345	0.0	0.00	1.17


SO. PLATTE TRIB. AT DENVER
19 JULY 1973
DISCHARGE
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
20.40
20.80
21.20
21.60
22.00
22.40
22.80
23.20
23.60
TIME (decimal)


SO. PLATTE TRIB. AT DENVER
19 JULY 1973
INCREMENTAL RAINFALL
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
20.40
20.80
21.20
21.60
22.00
22.40
22.80
23.20
23.60
TIME (decimal)


SO. PLATTE TRIB. AT DENVER
19 JULY 1973
ACCUMULATED RAINFALL
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
20.50
20.70
20.90
21.10
TIME (decimal)

Flood Reconstitution for Denver Goose Creek DGC 1

Storm Event 25 July 76

Runoff: depth = .30 inches, Q_p = 137 cfs at t_p = .75 hours

$R_{recession}$ = .32 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
441.6	21.5	.86	5	D		126	.75	.71	.37	.66	.05	Ø1	
"	15.4	"	"	U-1		98	.67	1.27	.55	.61	.04	Ø2	
"	"	"	"	D		129	.75	.70	.35	.61	.04	Ø3	← best

06728350 GOOSE CREEK AT BOULDER, COLO.

LOCATION.--Lat 40°01'35", long 105°16'19", in NW¼NE¼ sec.30, T.1 N., R.70 W., Boulder County, on left bank of concrete-lined channel, 30 ft (9 m) downstream from 19th St., and 150 ft (46 m) south of Balsam Ave., in Boulder.

DRAINAGE AREA.--0.69 mi² (1.78 km²), revised.

PERIOD OF RECORD.--May 7, 1971, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

REMARKS.--Basin drains residential areas.

STAGE-DISCHARGE RELATION.--Rating developed on basis of step-backwater analysis of reach of concrete-lined stream channel.

EXTREMES.--Water year 1975: Maximum discharge, 102 ft³/s (2.89 m³/s) June 7; no flow most of year.
Water year 1976: Maximum discharge, 137 ft³/s (3.88 m³/s) July 25; no flow most of year.
Water year 1977: Maximum discharge, 133 ft³/s (3.77 m³/s) July 20; no flow most of year.
Period of record: Maximum discharge, 185 ft³/s (5.24 m³/s) June 5, 1972; no flow most of each year.

RAINFALL MAY 18, 1975

RAINFALL, IN INCHES, DURING INDICATED INTERVAL

DATE	TIME	RAINFALL	DATE	TIME	RAINFALL	DATE	TIME	RAINFALL
5-18	0635	0.03	5-18	0640	0.01	5-18	0840	0.01
			5-18	0645	0.02			
			5-18	0800	0.01			

STORM TOTAL = 0.08

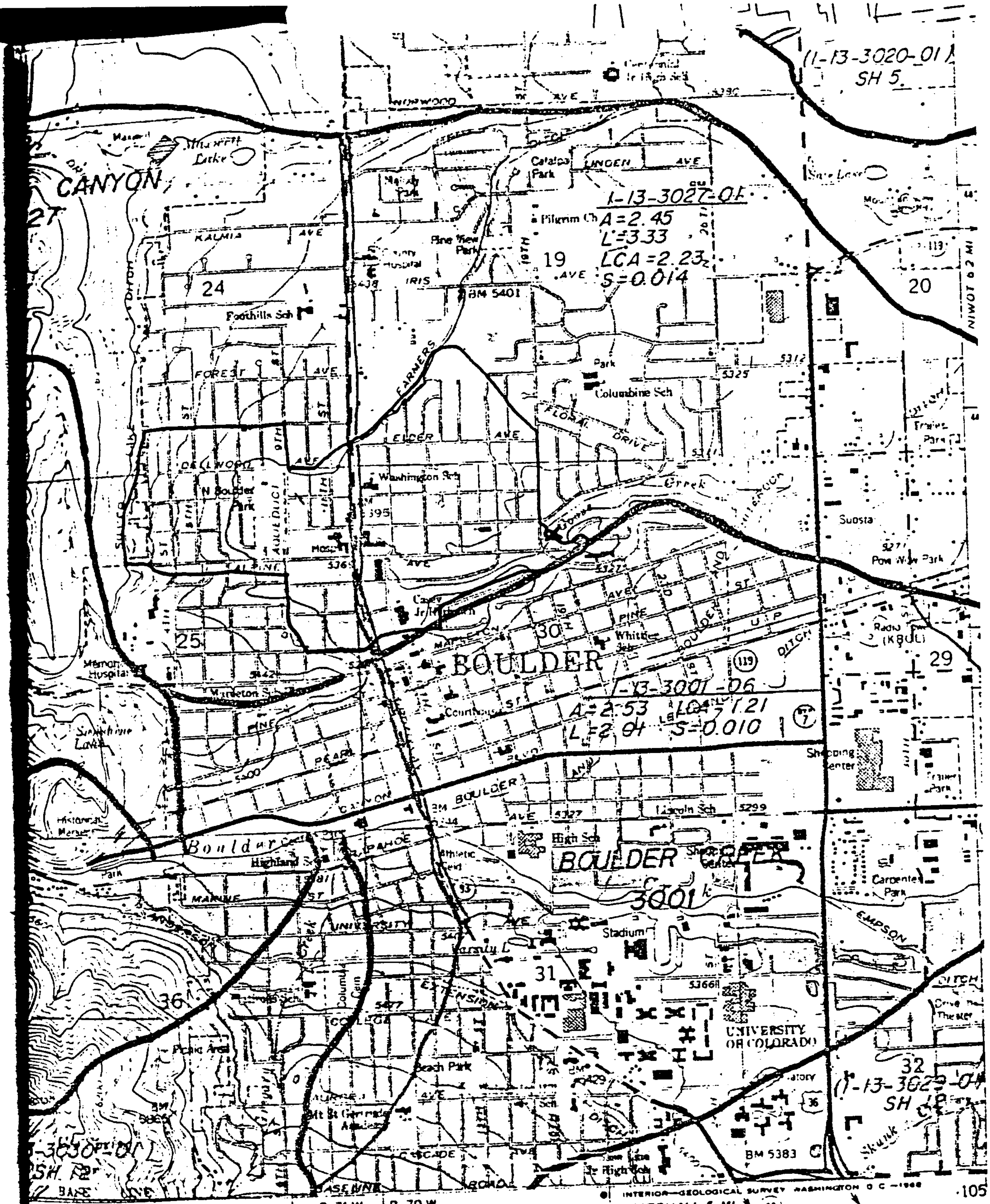
DURATION	5 MIN	15 MIN	30 MIN	1 HR
TIME	0630	0630	0630	0630
DEPTH	0.03	0.06	0.06	0.06
INTENSITY	0.36	0.24	0.12	0.06

RUNOFF MAY 18, 1975

DISCHARGE, IN CUBIC FEET PER SECOND, AT INDICATED TIME

DATE	TIME	DISCHARGE	DATE	TIME	DISCHARGE	DATE	TIME	DISCHARGE
5-18	0640	3.6	5-18	0705	0.8	5-18	0730	0.3
5-18	0645	4.4	5-18	0710	0.6	5-18	0735	0.3
5-18	0650	3.0	5-18	0715	0.5	5-18	0740	0.2
5-18	0655	1.5	5-18	0720	0.4	5-18	0745	0.1
5-18	0700	1.1	5-18	0725	0.3	5-18	0750	0.1

NOTE.--Discharge below 1.1 ft³/s estimated.



ROAD CLASSIFICATION

Heavy-duty — Light-duty

Medium-duty — Unimproved dirt

U. S. Route — State Route

1 MILE

NO. 4

BOULDER, COLO.

SE/4 BOULDER 15' QUADRANGLE

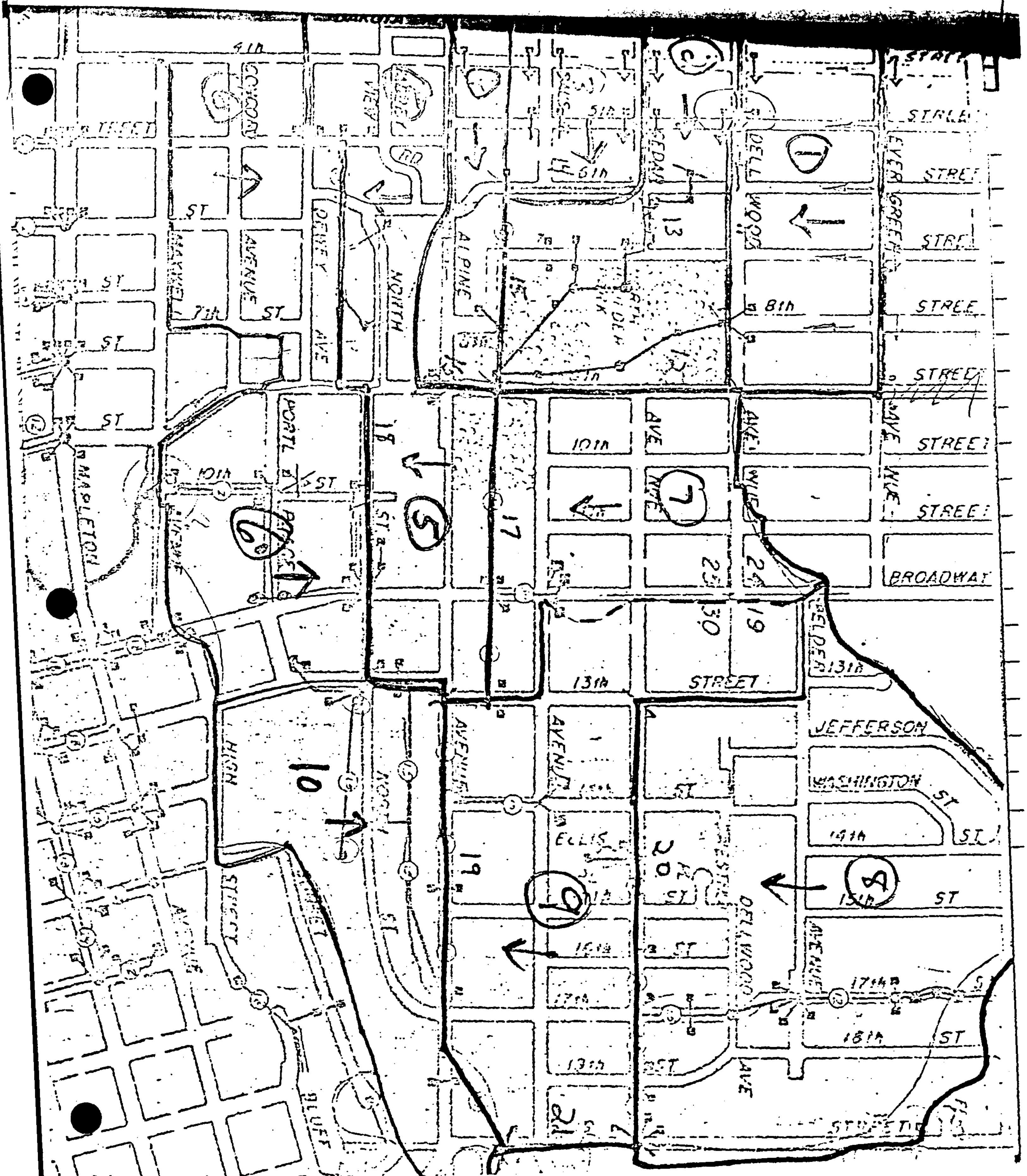
N4000-W10515/7.5

A= Area in Sq. Miles

L= Length in Miles

LCA= Length to Centroid of Area in Miles

S= Slope in Feet per Feet



4th
5th
6th
7th
8th
10th
STREET
BROADWAY
13th STREET
JEFFERSON
WASHINGTON ST
14th ST
15th ST
16th ST
17th
18th ST
ELLIS
DELLWOOD
EVERGREEN
ALPINE
DEWEY AVE
NORTH
HIGH STREET
MAPLETON
BLUFF
BELDEN
13
15
17
18
5
6
7
8
9
10
19
20
21
23
24
30

Goose Ck.

25 Jul 76 Lag = .63 T_c = 10:70 R = .65

area = 441.1 acres (.689 mi^2)

effect. imp. = 95.0 acres (21.5 %)

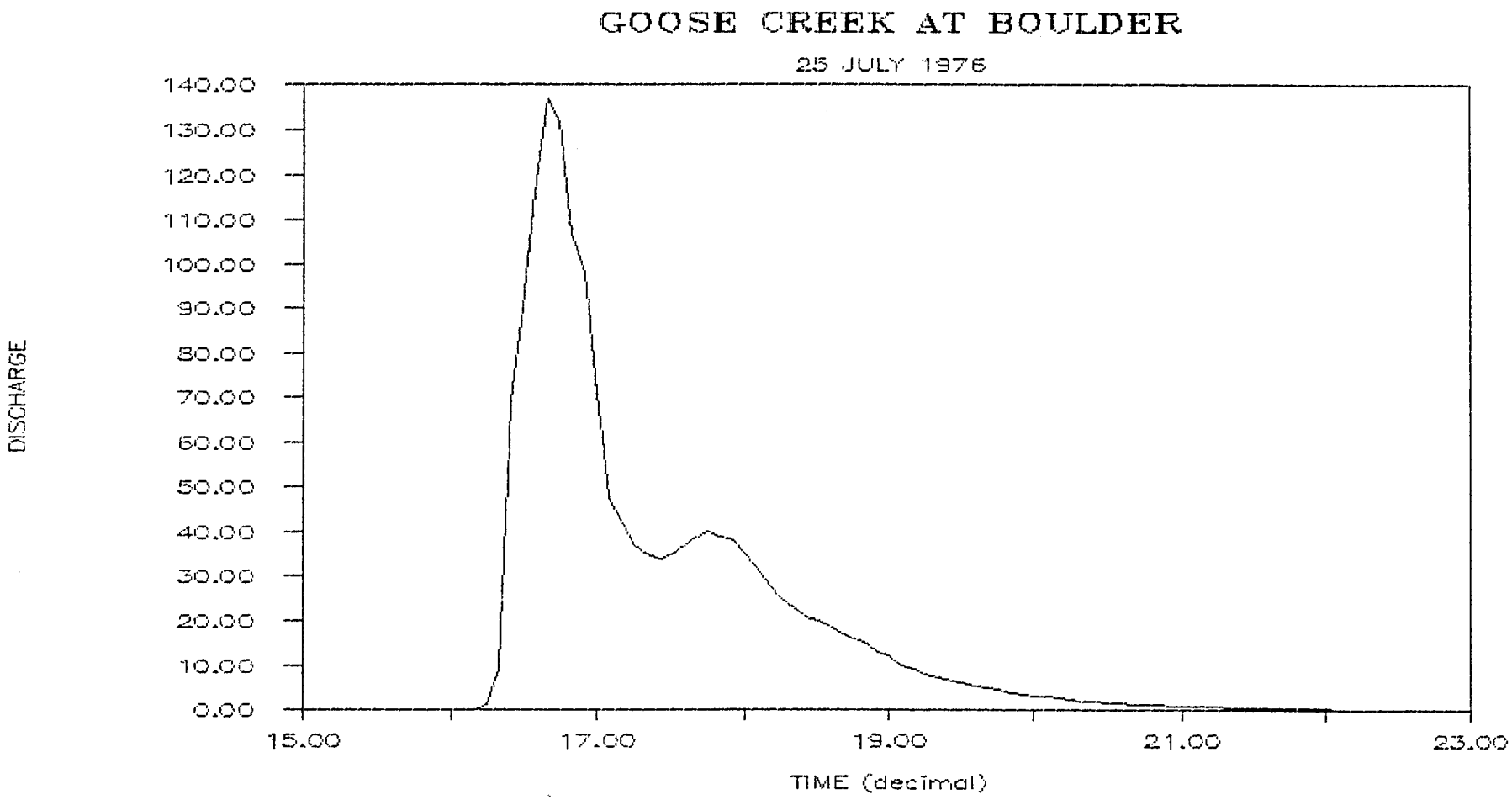
non-effect. imp. = 56.44 acres (12.8%)

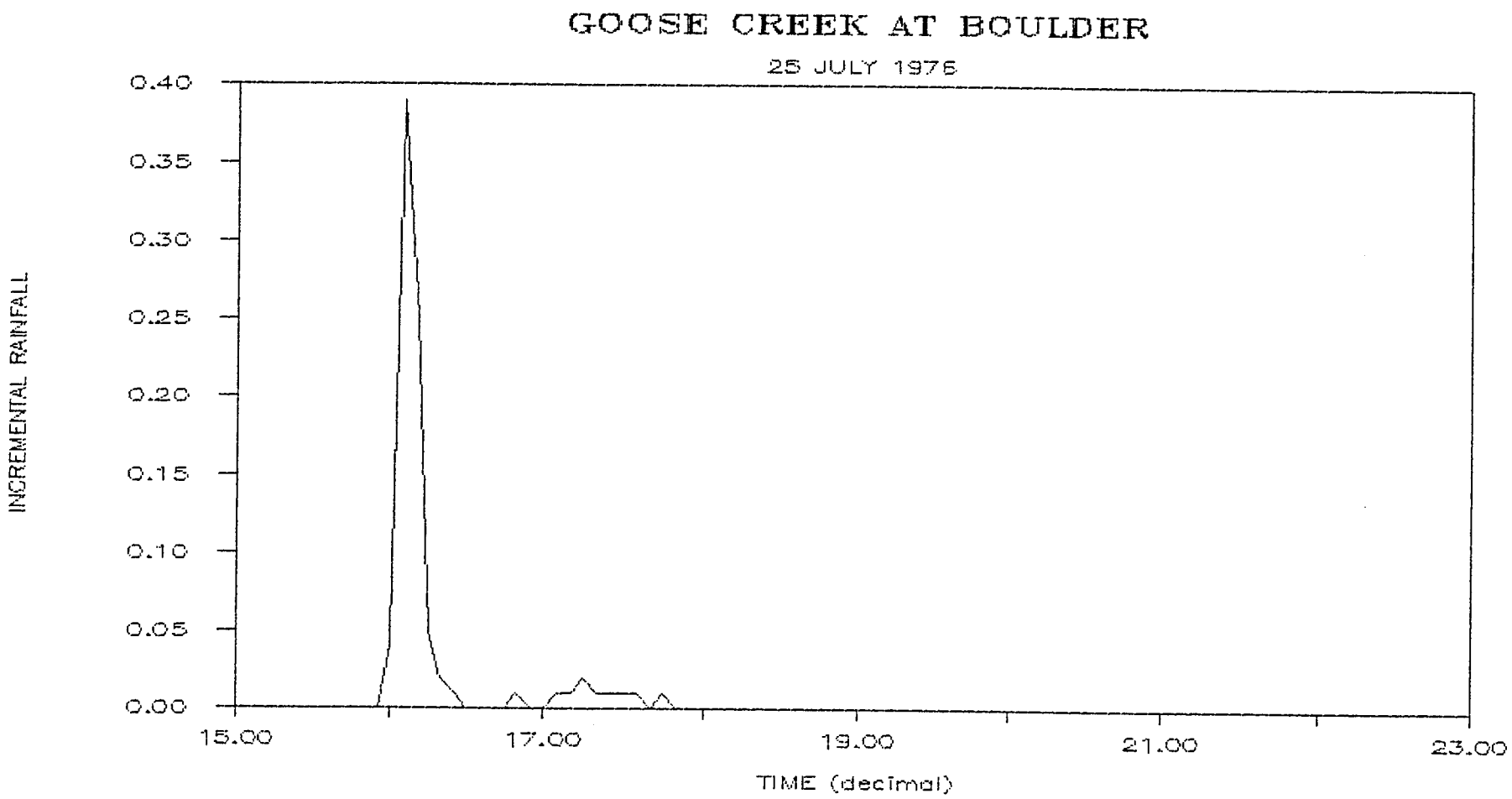
slopes: ft/ft .089, .075, .098, .077, .049, .043, .029, .021, .028, .090

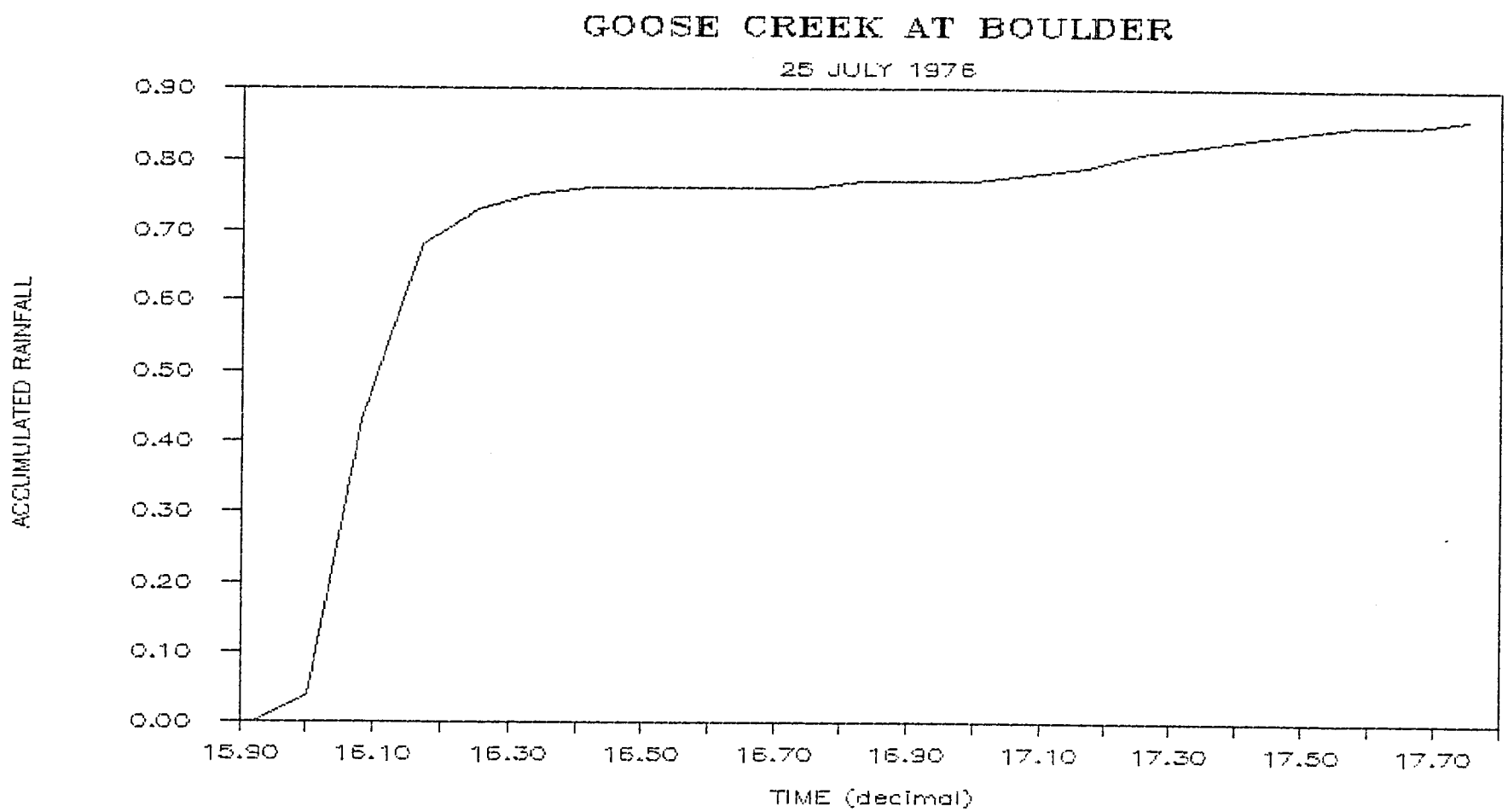
DENVER DATA
Goose Ck. at Boulder

DATE	TIME	Q	P1	SUM P1
25-Jul-76	1555	0.00	0.00	0.00
	1600	0.00	0.04	0.04
	1605	0.00	0.39	0.43
	1610	0.00	0.25	0.68
	1615	1.20	0.05	0.73
	1620	9.00	0.02	0.75
	1625	69.00	0.01	0.76
	1630	90.00	0.00	0.76
	1635	116.00	0.00	0.76
	1640	137.00	0.00	0.76
	1645	132.00	0.00	0.76
	1650	107.00	0.01	0.77
	1655	98.00	0.00	0.77
	1700	71.00	0.00	0.77
	1705	48.00	0.01	0.78
	1710	42.00	0.01	0.79
	1715	37.00	0.02	0.81
	1720	35.00	0.01	0.82
	1725	34.00	0.01	0.83
	1730	35.00	0.01	0.84
	1735	37.00	0.01	0.85
	1740	39.00	0.00	0.85
	1745	40.00	0.01	0.86
	1750	39.00	0.00	0.86
	1755	38.00	0.00	0.86
	1800	35.00	0.00	0.86
	1805	32.00	0.00	0.86
	1810	28.00	0.00	0.86
	1815	25.00	0.00	0.86
	1820	23.00	0.00	0.86
	1825	21.00	0.00	0.86
	1830	20.00	0.00	0.86
	1835	19.00	0.00	0.86
	1840	17.00	0.00	0.86
	1845	16.00	0.00	0.86
	1850	15.00	0.00	0.86
	1855	13.00	0.00	0.86
	1900	12.00	0.00	0.86
	1905	10.00	0.00	0.86
	1910	9.00	0.00	0.86
	1915	8.10	0.00	0.86
	1920	7.30	0.00	0.86
	1925	6.60	0.00	0.86
	1930	6.00	0.00	0.86
	1935	5.40	0.00	0.86
	1940	4.90	0.00	0.86
	1945	4.40	0.00	0.86
	1950	4.00	0.00	0.86
	1955	3.50	0.00	0.86
	2000	3.20	0.00	0.86
	2005	2.90	0.00	0.86
	2010	2.60	0.00	0.86
	2015	2.40	0.00	0.86
	2020	2.10	0.00	0.86
	2025	1.90	0.00	0.86
	2030	1.70	0.00	0.86
	2035	1.60	0.00	0.86
	2040	1.40	0.00	0.86

2045	1.30	0.00	0.86
2050	1.20	0.00	0.86
2055	1.00	0.00	0.86
2100	0.90	0.00	0.86
2105	0.90	0.00	0.86
2110	0.80	0.00	0.86
2115	0.70	0.00	0.86
2120	0.60	0.00	0.86
2125	0.60	0.00	0.86
2130	0.50	0.00	0.86
2135	0.40	0.00	0.86
2140	0.40	0.00	0.86
2145	0.40	0.00	0.86
2150	0.30	0.00	0.86
2155	0.30	0.00	0.86
2200	0.30	0.00	0.86
2205	0.20	0.00	0.86
2210	0.20	0.00	0.86
2215	0.20	0.00	0.86
2220	0.20	0.00	0.86
2225	0.20	0.00	0.86
2230	0.10	0.00	0.86
2235	0.10	0.00	0.86
2240	0.10	0.00	0.86
2245	0.10	0.00	0.86
2250	0.10	0.00	0.86
2350	0.0	0 0	0.86


GOOSE CREEK AT BOULDER
25 JULY 1976
DISCHARGE
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
15.00
17.00
19.00
21.00
23.00
TIME (decimal)


GOOSE CREEK AT BOULDER
25 JULY 1976
INCREMENTAL RAINFALL
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
15.00
17.00
19.00
21.00
23.00
TIME (decimal)


GOOSE CREEK AT BOULDER
25 JULY 1976
ACCUMULATED RAINFALL
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
15.90
16.10
16.30
16.50
16.70
16.90
17.10
17.30
17.50
17.70
TIME (decimal)

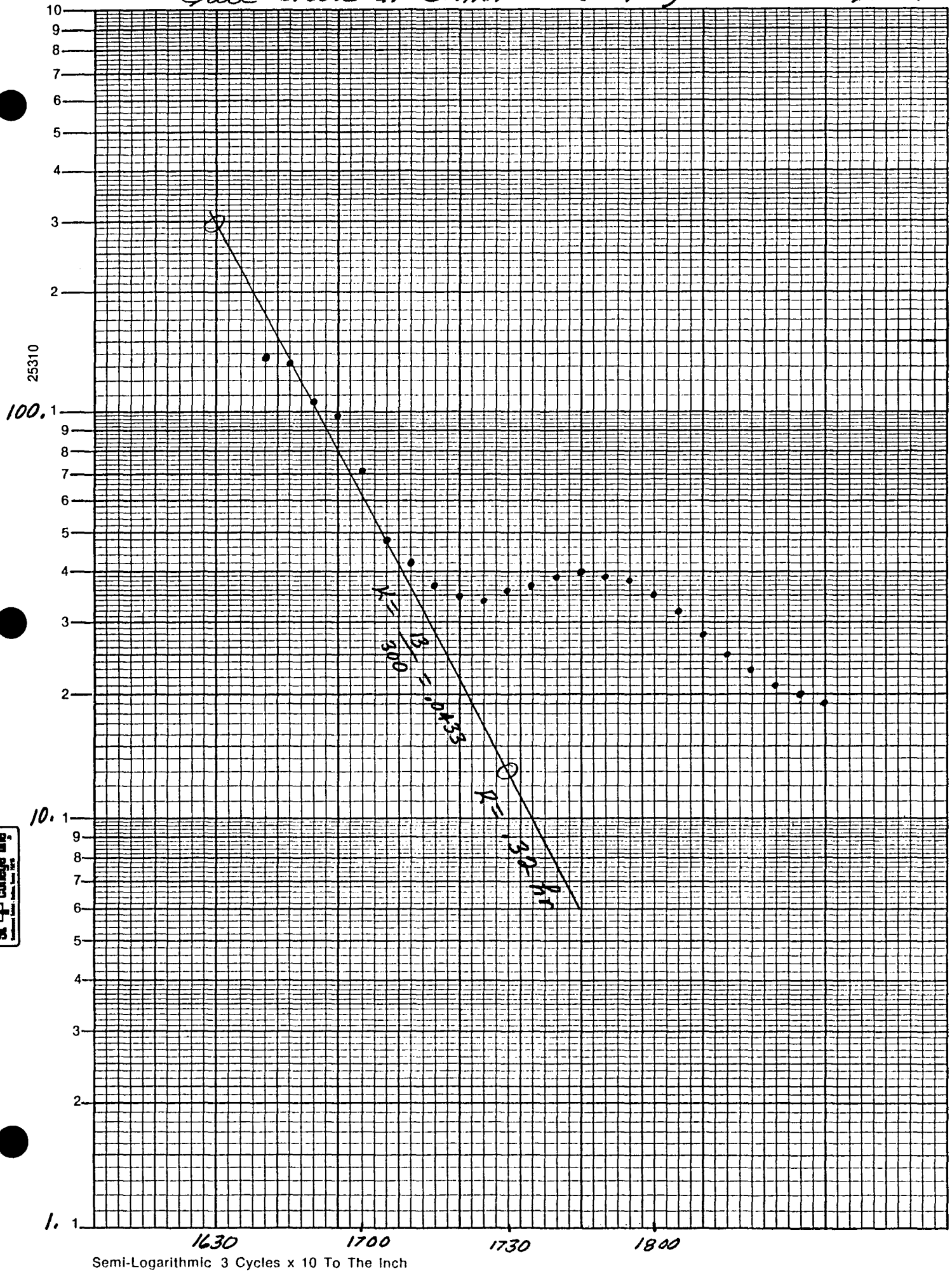
21 Oct 87

Analysis of Effective Impervious Area
Goose Creek at Boulder (441.6 acres)

Storm Date	Rain	Runoff Volume	Runoff Q_p		A_e
	inch	ac-ft	cfs		acres
(1)	(2)	(3)	(4)		(5)
16 July 75	.29	1.60	10		66.2
11 Sept 75	.30	1.69	16		67.6
29-30 April 75	.80	4.72	10		70.8
15 April 77	.77	20.14	25	← peak is too high	× 314.0

avg. A_e = 68.2 acres (15.4 %)

Goose Creek at Denver (DGC) 9 Sept 87



Flood Reconstitution for Denver Sand Creek DSC1

Storm Event 30 July 74

Runoff: depth = .52 inches, Q_p = 251 cfs at t_p = .42 hours

$R_{recession}$ = .16 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
185.6	32	1.38	5	D	comp/obs runoff=.85	215	.42	.27	.05	1.61	.21	Ø1	
"	24	"	"	"		262	.42	.09	.14	.79	1.12	Ø2	
"	"	"	2	"		280	.50	.14	.07	1.00	.38	Ø3	
"	"	"	"	U-1		255	.43	.11	.16	.74	1.33	Ø4	← best

Flood Reconstitution for Denver Sand Creek DSC 2

Storm Event 1 Aug 76

Runoff: depth = .42 inches, Q_p = 196 cfs at t_p = .42 hours

$R_{recession}$ = .18 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
185.6	32	1.30	5	D		185	.42	.19	.12	1.30	.26	Ø1	
"	24	"	2	U-1		219	.40	.27	.11	.95	.55	Ø2	← selected

06714310 SAND CREEK TRIBUTARY AT DENVER, COLO.

LOCATION.--Lat 39°47'07", long 104°50'31", in SW¼SW¼ sec.13, T.3 S., R.67 W., Denver County, on left bank of concrete-lined drainage ditch in the median of Andrews Dr. Pkwy., 50 ft (15 m) downstream from Troy St. in Denver.

DRAINAGE AREA.--0.29 mi^2 (0.75 km^2), revised.

PERIOD OF RECORD.--Apr. 27, 1971, to current year (no winter records).

GAGE.--Flood-hydrograph and rainfall recorders (dual digitals).

REMARKS.--Basin drains residential area.

STAGE-DISCHARGE RELATION.--Rating developed on basis of step-backwater analysis of reach of concrete-lined stream channel and discharge measurements at discharges of 4.5 ft^3/s (0.13 m^3/s) and 37 ft^3/s (1.05 m^3/s).

EXTREMES.--Water year 1975: Maximum discharge, 53 ft^3/s (1.50 m^3/s) Aug. 13; no flow most of year.
Water year 1976: Maximum discharge, 196 ft^3/s (5.55 m^3/s) Aug. 1; no flow most of year.
Water year 1977: Maximum discharge, 94 ft^3/s (2.66 m^3/s) July 20; no flow most of year.
Period of record: Maximum discharge, 251 ft^3/s (7.11 m^3/s) July 30, 1974; no flow most of each year.

RAINFALL OCT. 30,1974

RAINFALL, IN INCHES, DURING INDICATED INTERVAL

DATE	TIME	RAINFALL	DATE	TIME	RAINFALL	DATE	TIME	RAINFALL
10-30	0155	0.03	10-30	1525	0.02	10-30	1555	0.02
10-30	0200	0.03	10-30	1535	0.02	10-30	1600	0.01
10-30	0230	0.01	10-30	1540	0.01	10-30	1605	0.01
			10-30	1545	0.01			
			10-30	1550	0.01			

STORM TOTAL = 0.18

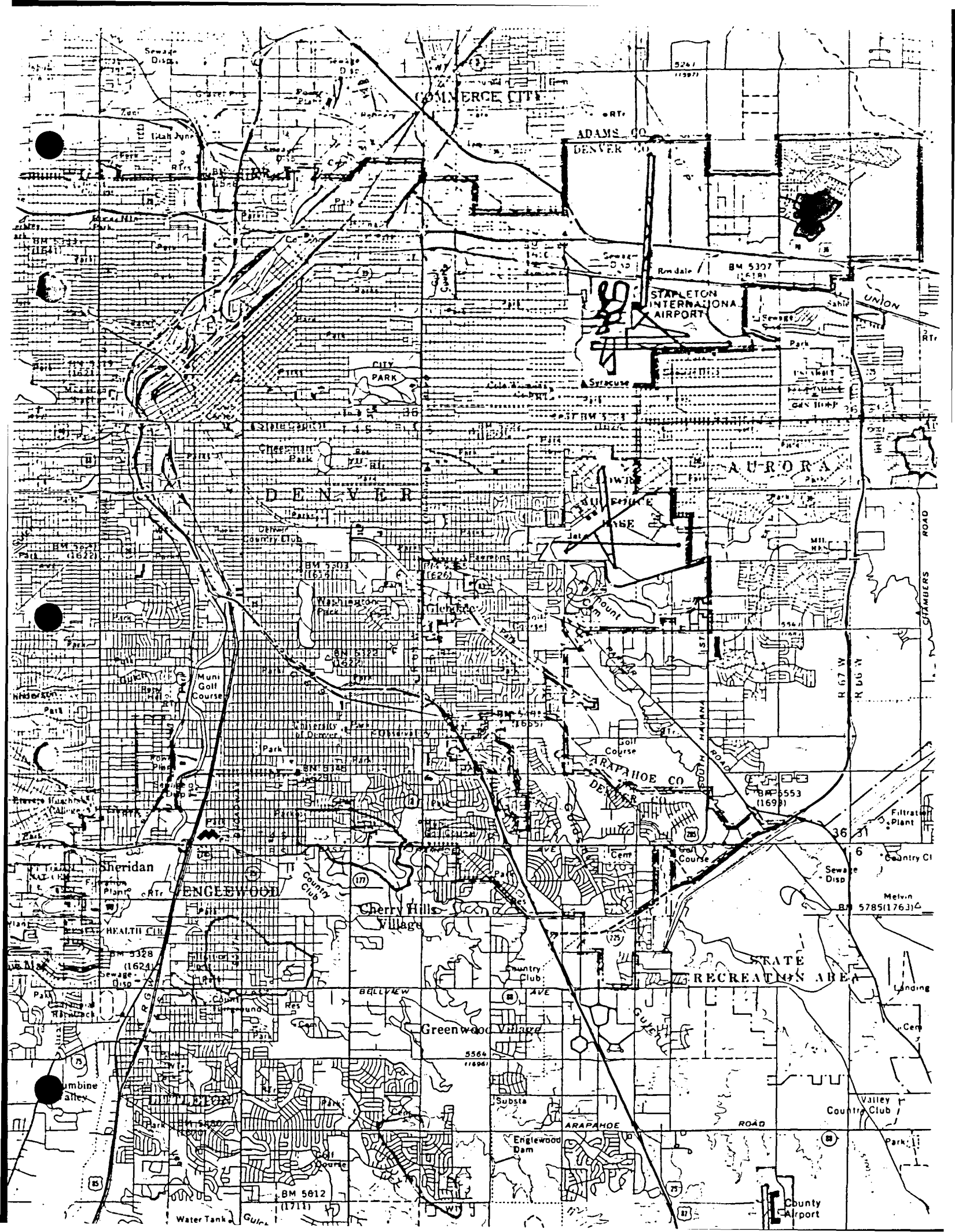
DURATION	5 MIN	15 MIN	30 MIN	1 HR
TIME	0150	0150	1530	1520
DEPTH	0.03	0.06	0.08	0.11
INTENSITY	0.36	0.24	0.16	0.11

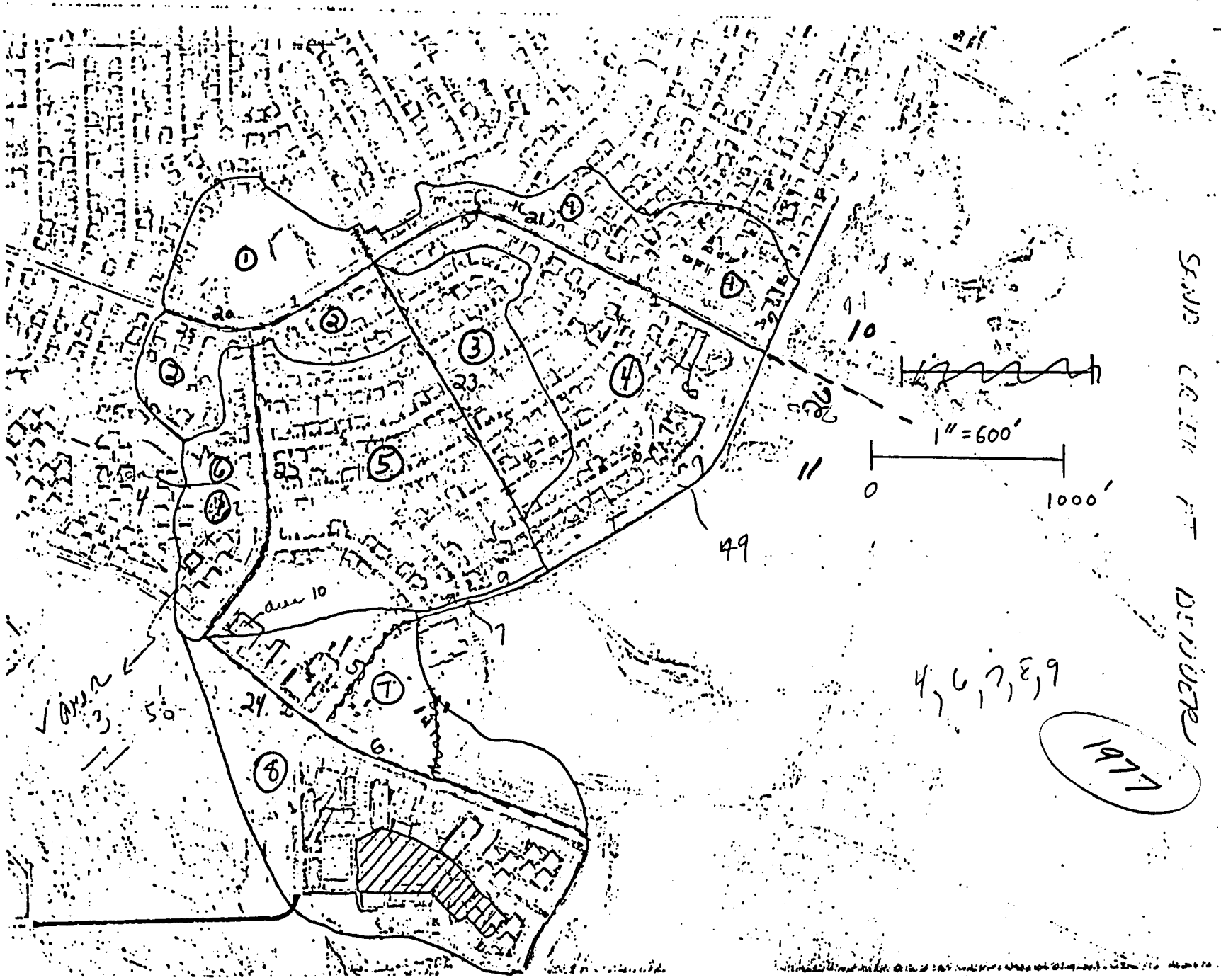
RUNOFF OCT. 30,1974

DISCHARGE, IN CUBIC FEET PER SECOND, AT INDICATED TIME

DATE	TIME	DISCHARGE	DATE	TIME	DISCHARGE	DATE	TIME	DISCHARGE
10-30	1530	2.0	10-30	1610	3.0	10-30	1650	1.1
10-30	1535	6.8	10-30	1615	2.7	10-30	1655	0.9
10-30	1540	11	10-30	1620	2.4	10-30	1700	0.7
10-30	1545	4.9	10-30	1625	2.2	10-30	1705	0.6
10-30	1550	4.2	10-30	1630	1.9	10-30	1710	0.4
10-30	1555	3.9	10-30	1635	1.7	10-30	1715	0.3
10-30	1600	3.7	10-30	1640	1.4	10-30	1720	0.2
10-30	1605	3.3	10-30	1645	1.2	10-30	1725	0.1

NOTE.--Discharge below 3.7 ft^3/s estimated.


COMMERCE CITY
ADAMS CO
DENVER CO
STAPLETON INTERNATIONAL AIRPORT
UNION
CITY PARK
Cheesman Park
DENVER
AURORA
Denver Country Club
Washington Park
Glendale
Muni Golf Course
University of Denver
ARAPAHOE CO
DENVER CO
Filtration Plant
Sheridan
ENGLEWOOD
Cherry Hills Village
HEALTH CTR
STATE RECREATION AREA
Greenwood Village
LITTLETON
Valley Country Club
Englewood Dam
County Airport
Water Tank
BM 5612 (1711)
BM 5328 (1624)
BM 5553 (1698)
BM 5785 (1763)
BM 5307
ARAPAHOE ROAD
HAVANA ROAD
CHAMBERS ROAD
BELLVIEW AVE
Melvin


1" = 600'
0
1000'
49
4, 6, 7, 8, 9
1977

1980

Sand Ck 11 Sept 87

Basin Characteristics (1971-1974)

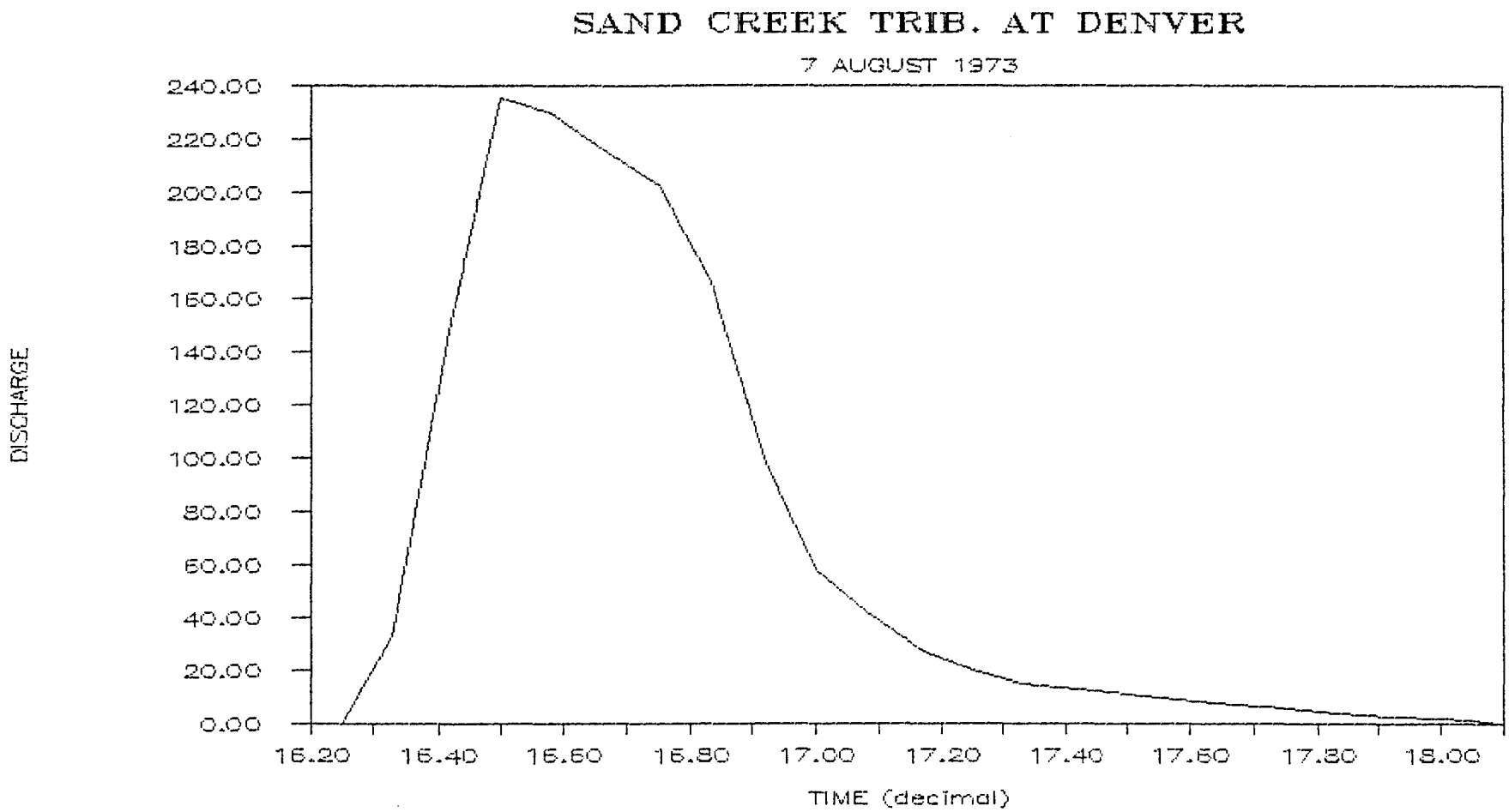
Area = .29 mi^2

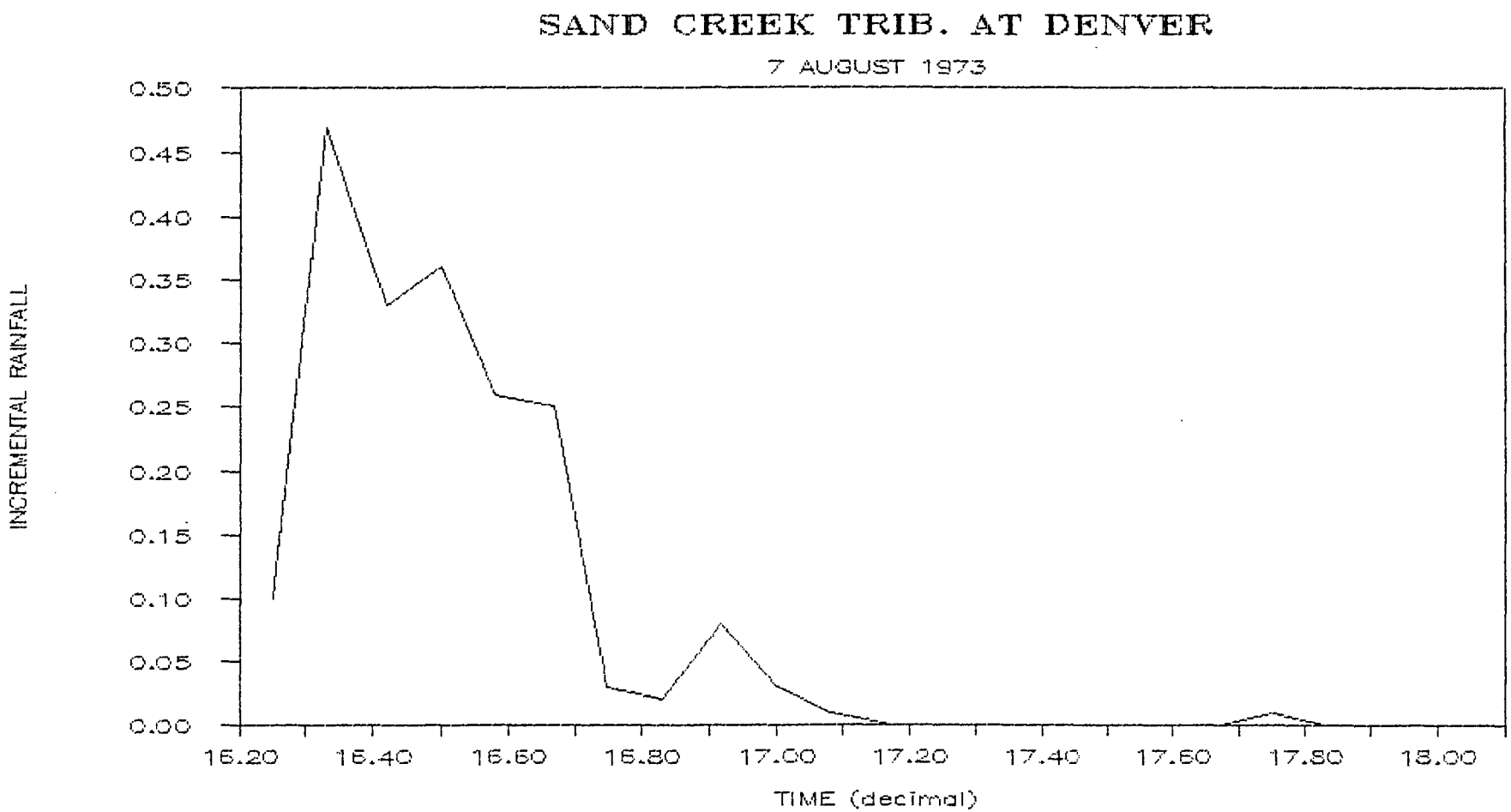
% Imp. = 32

L = .84 mi

L_{ca} = .21 mi

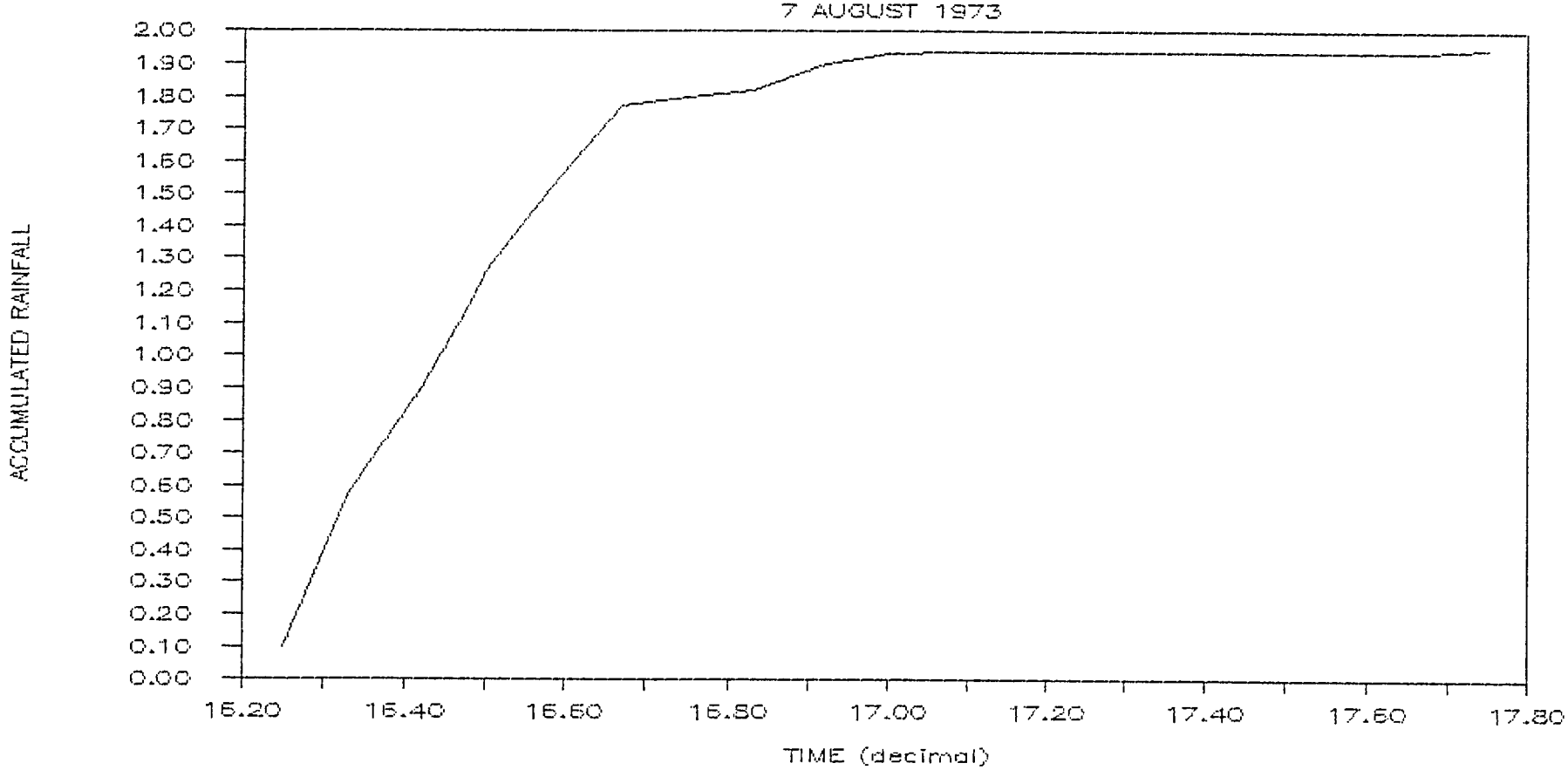
DENVER DATA	DATE	TIME	Q	P1	SUM P1
Sand Ck. trib at Denver	07-Aug-73	1615	0.00	0.10	0.10
		1620	33.00	0.47	0.57
		1625	155.00	0.33	0.90
		1630	236.00	0.36	1.26
		1635	230.00	0.26	1.52
		1640	215.00	0.25	1.77
		1645	203.00	0.03	1.80
		1650	168.00	0.02	1.82
		1655	98.00	0.08	1.90
		1700	58.00	0.03	1.93
		1705	42.00	0.01	1.94
		1710	27.00	0.00	1.94
		1715	20.00	0.00	1.94
		1720	15.00	0.00	1.94
		1725	13.00	0.00	1.94
		1730	11.00	0.00	1.94
		1735	9.00	0.00	1.94
		1740	7.00	0.00	1.94
		1745	6.00	0.01	1.95
		1750	4.00	0.00	1.95
		1755	3.00	0.00	1.95
		1800	2.00	0.00	1.95
		1805	1.00	0.00	1.95
		1810	0.00	0.00	1.95


SAND CREEK TRIB. AT DENVER
7 AUGUST 1973
DISCHARGE
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
16.20
16.40
16.60
16.80
17.00
17.20
17.40
17.60
17.80
18.00
TIME (decimal)

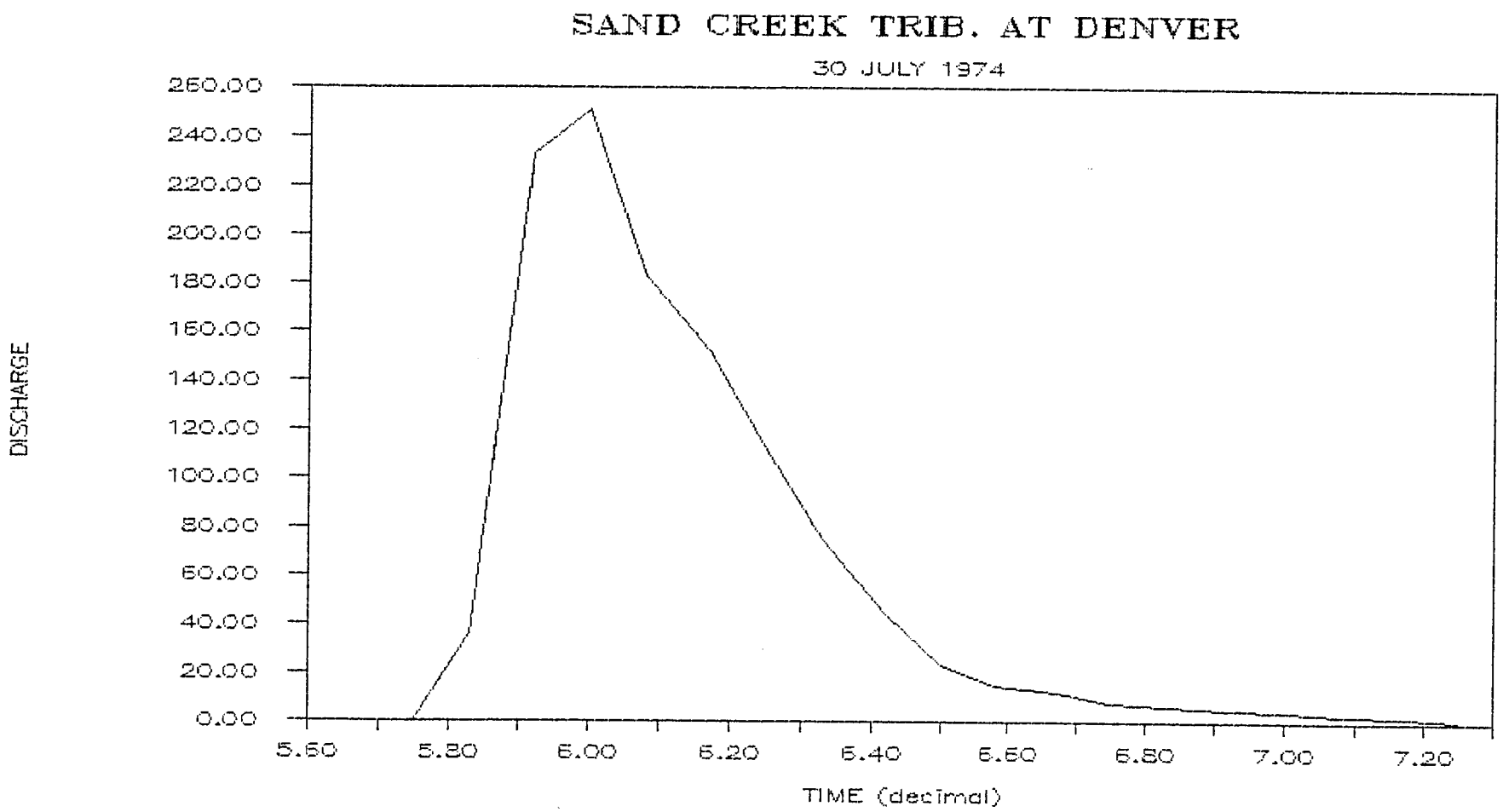

SAND CREEK TRIB. AT DENVER
7 AUGUST 1973
INCREMENTAL RAINFALL
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
16.20
16.40
16.60
16.80
17.00
17.20
17.40
17.60
17.80
18.00
TIME (decimal)

SAND CREEK TRIB. AT DENVER

7 AUGUST 1973

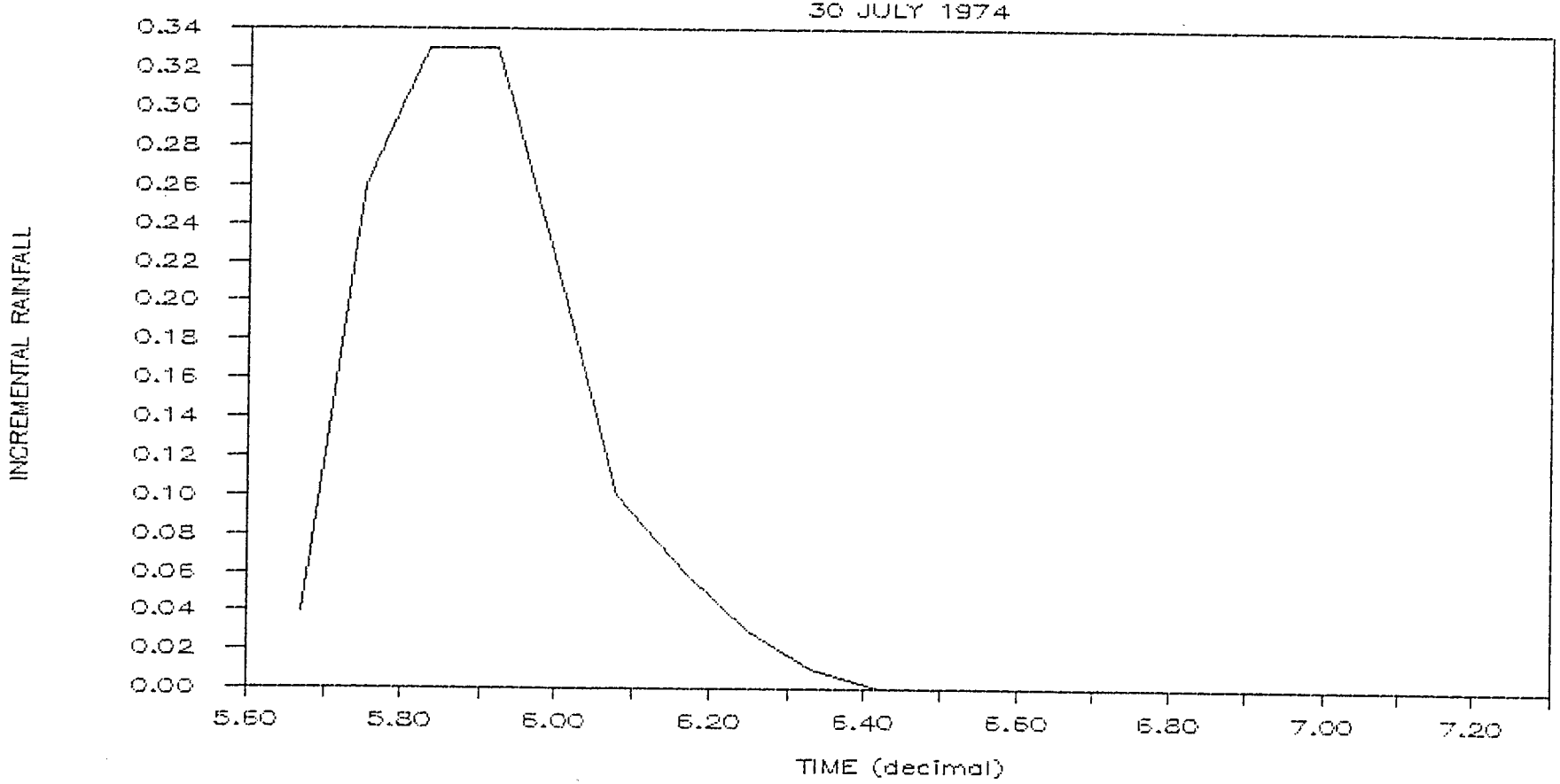


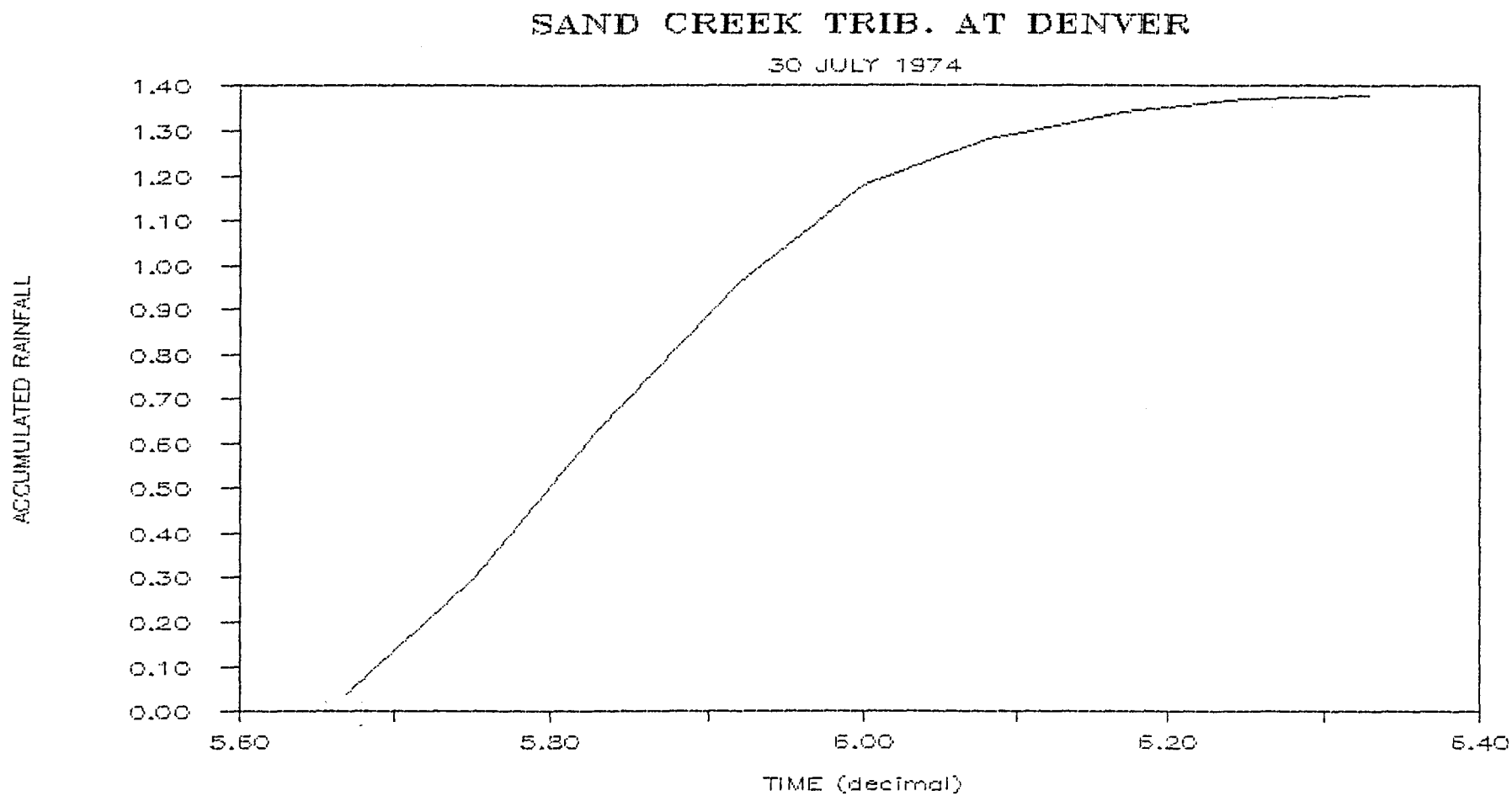
DENVER DATA	DATE	TIME	Q	P1	SUM P1
Sand Ck. trib at Denver	30-Jul-74	540	0.00	0.04	0.04
		545	0.00	0.26	0.30
		550	36.00	0.33	0.63
		555	233.00	0.33	0.96
		600	251.00	0.22	1.18
		605	183.00	0.10	1.28
		610	152.00	0.06	1.34
		615	113.00	0.03	1.37
		620	75.00	0.01	1.38
		625	44.00	0.00	1.38
		630	23.00	0.00	1.38
		635	15.00	0.00	1.38
		640	12.00	0.00	1.38
		645	7.50	0.00	1.38
		650	6.50	0.00	1.38
		655	5.30	0.00	1.38
		700	4.70	0.00	1.38
		705	3.00	0.00	1.38
		710	2.00	0.00	1.38
		715	1.00	0.00	1.38
		720	0.0	0.0	1.38


SAND CREEK TRIB. AT DENVER
30 JULY 1974
DISCHARGE
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
5.60
5.80
6.00
6.20
6.40
6.60
6.80
7.00
7.20
TIME (decimal)

SAND CREEK TRIB. AT DENVER

30 JULY 1974




SAND CREEK TRIB. AT DENVER
30 JULY 1974
ACCUMULATED RAINFALL
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5.60
5.80
6.00
6.20
6.40
TIME (decimal)

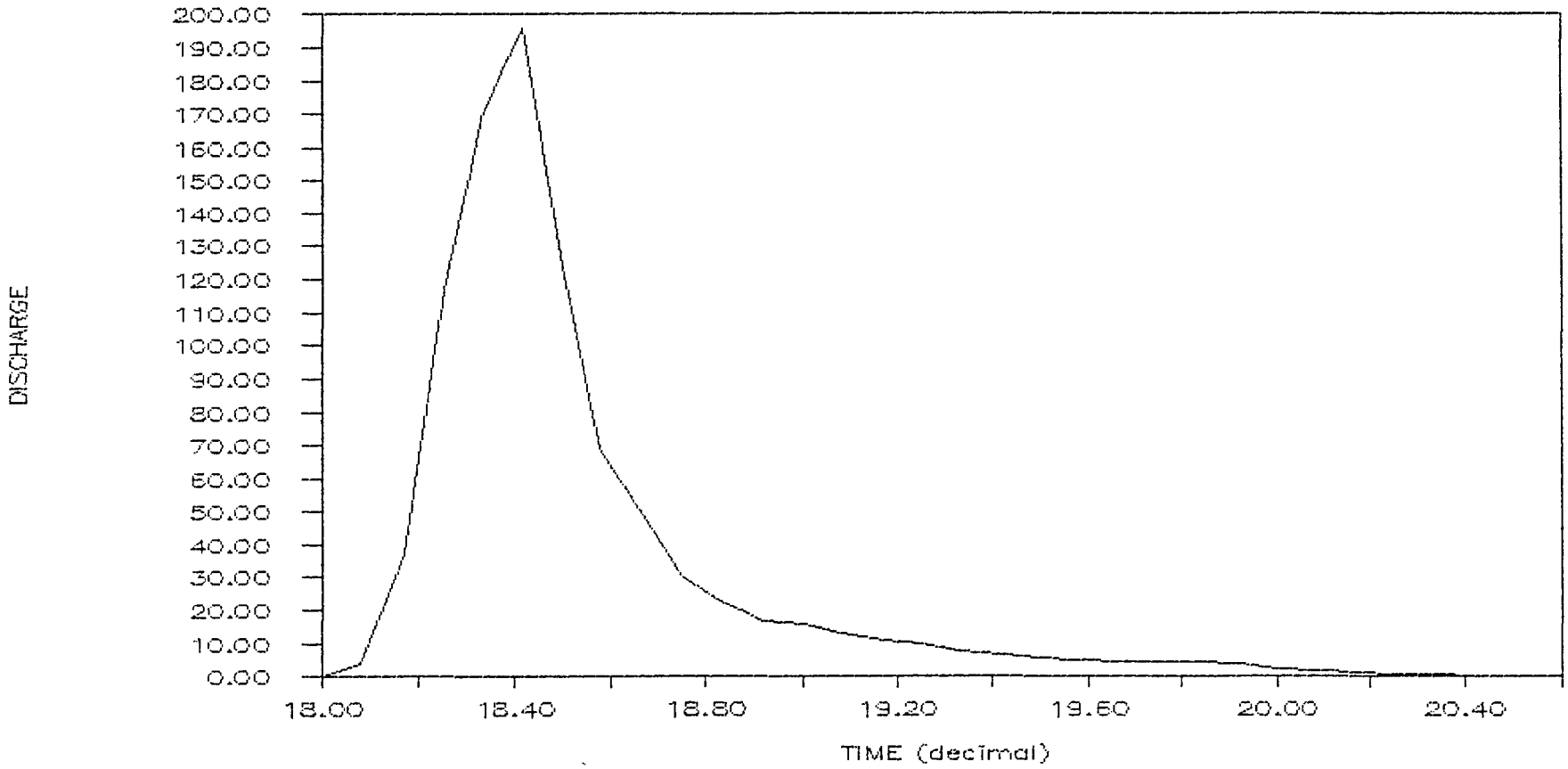
DENVER DATA

Sand Ck. trib at Denver

DATE	TIME	Q	P1	SUM P1
01-Aug-76	1800	0.00	0.00	0.00
	1805	3.70	0.10	0.10
	1810	37.00	0.35	0.45
	1815	117.00	0.35	0.80
	1820	169.00	0.29	1.09
	1825	196.00	0.06	1.15
	1830	124.00	0.05	1.20
	1835	69.00	0.04	1.24
	1840	49.00	0.03	1.27
	1845	30.00	0.01	1.28
	1850	23.00	0.00	1.28
	1855	17.00	0.01	1.29
	1900	16.00	0.00	1.29
	1905	13.00	0.01	1.30
	1910	11.00	0.00	1.30
	1915	9.80	0.00	1.30
	1920	7.50	0.00	1.30
	1925	6.30	0.00	1.30
	1930	5.30	0.00	1.30
	1935	4.90	0.00	1.30
	1940	4.50	0.00	1.30
	1945	4.30	0.00	1.30
	1950	4.10	0.00	1.30
	1955	3.90	0.00	1.30
	2000	2.50	0.00	1.30
	2005	1.60	0.00	1.30
	2010	1.10	0.00	1.30
	2015	0.70	0.00	1.30
	2020	0.50	0.00	1.30
	2025	0.30	0.00	1.30
	2030	0.20	0.00	1.30
	2035	0.10	0.00	1.30
	2040	0.0	0.0	1.30

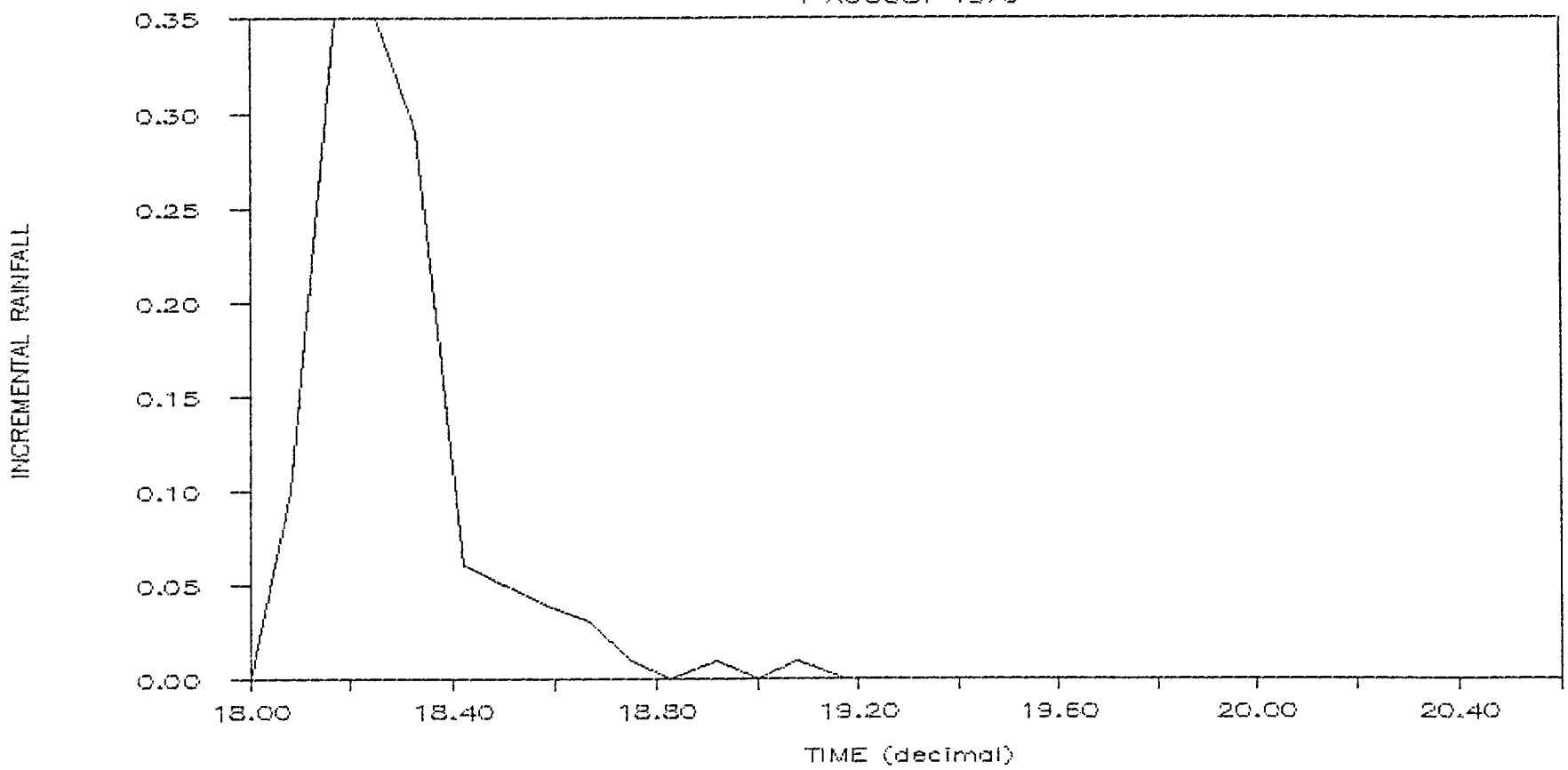
SAND CREEK TRIB. AT DENVER

1 AUGUST 1976



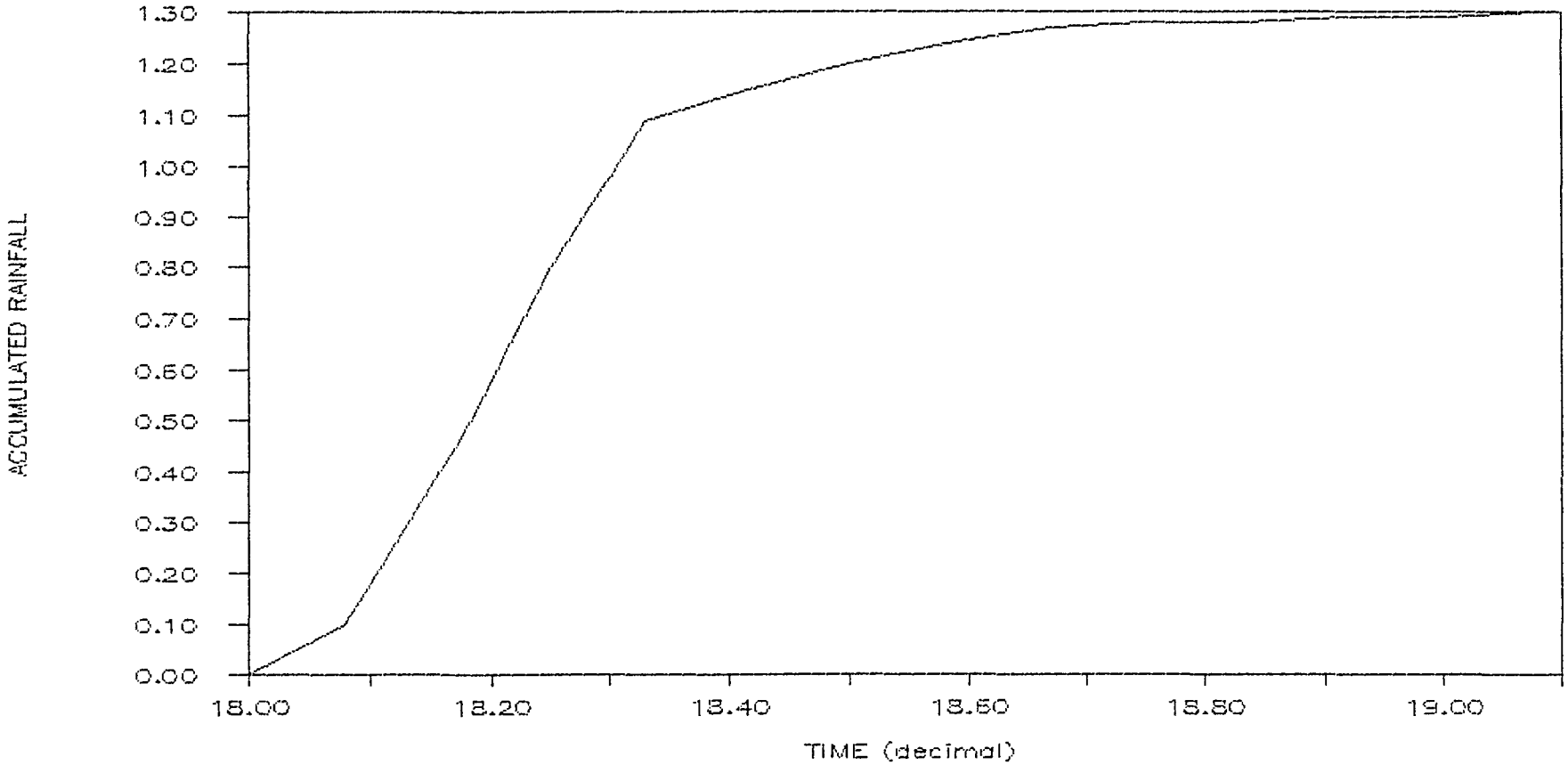
SAND CREEK TRIB. AT DENVER

1 AUGUST 1976



SAND CREEK TRIB. AT DENVER

1 AUGUST 1976



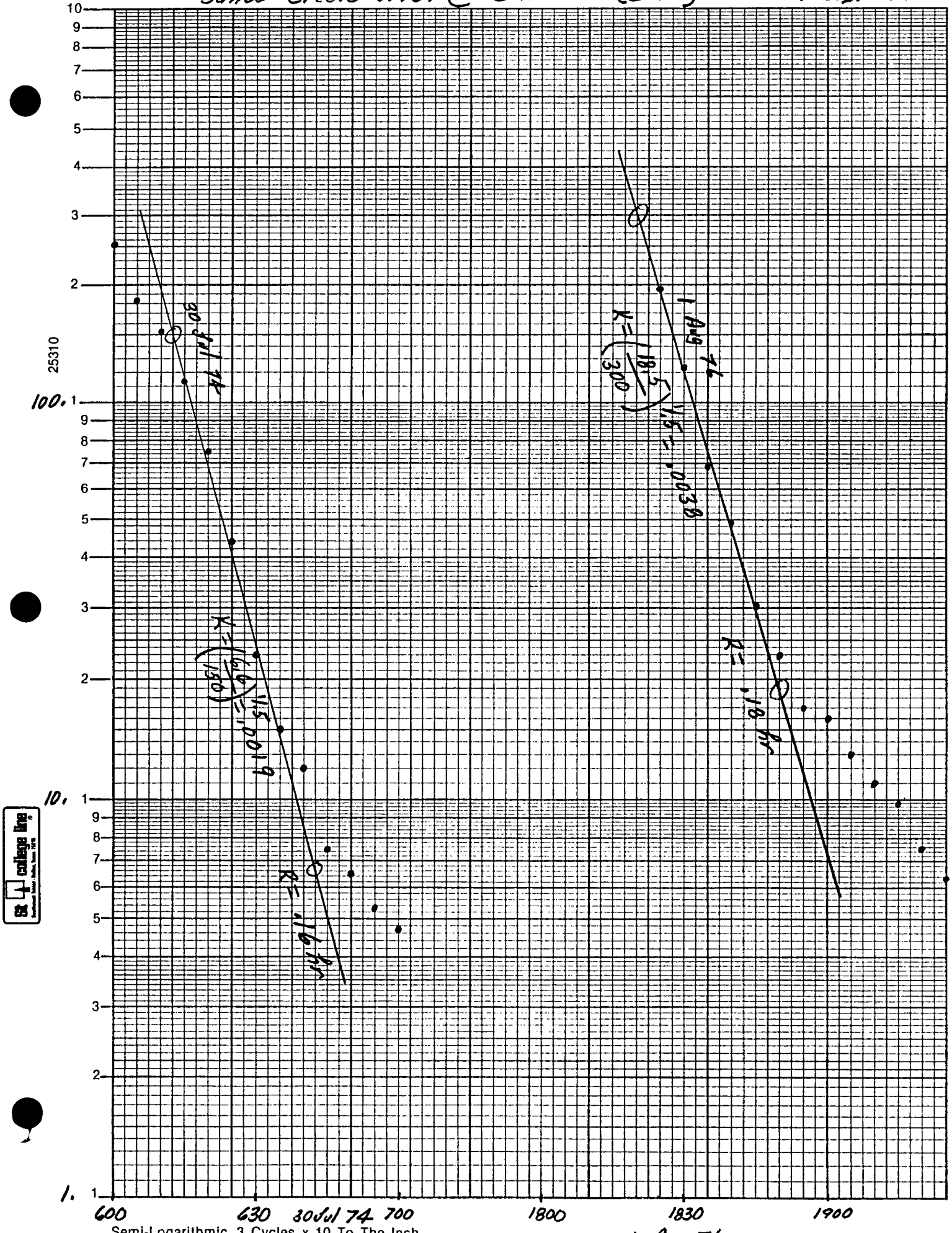
21 Oct 87

Analysis of Effective Impervious Area
Sand Creek Trib. @ Denver (185.6 acres)

Storm Date	Rain in.	Runoff Volume ac-ft	Qp cfs	Ae acres
(1)	(2)	(3)	(4)	(5)
30 Oct 74	.18	.42	11	27.8
21-22 May 76	.82	3.08	7.8	45.1
7 Sept 76	.27	1.31	7.5	58.4
18-19 June 77	.16	.54	6.3	40.3
16 Aug 77	.20	.85	8.0	50.7

Avg. Ae = 44.5 acres (24 %)

Sand Creek trib. @ Denver (DSC) 9 Sept 87



APPENDIX 3-H

Flood reconstitutions and worksheets, Wyoming.

C>

Volume in drive A has no label
Directory of A:\

WCU1	I04	608	8-28-87	5:20p
WCU1	004	24199	8-28-87	5:22p
WCU2	I05	643	9-08-87	9:39p
WCU2	005	23413	9-08-87	9:42p
WC1	I05	634	9-08-87	11:00p
WC1	005	22257	9-08-87	11:02p
WC2	I03	745	8-29-87	1:14a
WC2	003	22806	8-29-87	1:15a
WDH1	I02	548	8-31-87	8:41a
WDH1	002	22436	8-31-87	8:43a
WET1	I01	501	8-31-87	8:51a
WET1	001	22416	8-31-87	8:52a
WD1	I02	578	9-08-87	11:54p
WD1	002	22692	9-08-87	11:55p
WHD1	I01	432	8-31-87	9:11a
WHD1	001	19953	8-31-87	9:12a
WMB1	I02	534	9-09-87	1:02a
WMB1	002	22291	9-09-87	1:03a
WCU1	I5	611	10-22-87	2:17a
WCU1	05	24569	10-22-87	2:21a
WET1	I4	536	10-22-87	3:49a
WET1	04	22204	10-22-87	3:51a

22 File(s) 98304 bytes free

Table 4.- Continued

Station	Storm Date	Rainfall Depth inches	Rainfall Max Intensity in/hr	Rainfall Duration hr-min	Runoff Peak Discharge cfs	Runoff Depth inches
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Wyoming				
WCU W. Fk. Dry Cheyenne Creek at upper station	12 Jun 67	1.04	4.2	2-20	168.	.33
	10 Jun 69	1.60	6.4	2-10	275.	.93
WC W. Fk. Dry Cheyenne Creek trib.	10 Jun 69	1.28	5.0	2-1-	421.	.51
	5 Jun 72	2.34	9.6	3-25	1,260.	1.22
WDH Dead Horse Creek tributary	3 Jun 72	1.23	11.4	0-20	2,040.	1.11
WET East Teapot Creek	10 Jun 65	1.56	4.0	1-30	4,450.	.63
WD Dugout Creek tributary	24 Jun 65	.91	5.6	1-10	493.	.50
WHD Headgate Draw at upper station	16 Jul 69	1.39	5.8	0-35	1,670.	.38
WMB Medicine Bow River tributary	28 Jun 73	1.02	6.8	0-40	679.	.35

✓ 06238760	W. Fk. Dry Cheyenne Ck @ upper station
✓ 06238780	W. Fk. Dry Cheyenne Ck trib. nr. Riverton
✓ 06312910	Dead Horse Ck. trib. nr. Midwest
✓ 06313050	East Teapot Ck. nr. Edgerton
✓ 06313180	Dugout Ck. trib. nr. Midwest
✓ 06316480	Headgate Draw at upper station, nr. Buffalo
✓ 06634910	Medicine Bow River trib. near Hanna

Selection of Wyoming events for data entry, tabulating, & plotting

station (1)	Date (2)	Start Time (3)	End Time (4)	# of Raingages (5)	Report (6)	pg (7)	File Name (8)
W. Fk. Dry Cheyenne Ck. @ upper station	12 Jun 67	1710	(0745) 0345	1	#17	22	WCU1
	10 Jun 69	1535	2340	1		26	WCU2
W. Fk. Dry Cheyenne Ck. trib. nr. Riverton, WY	10 Jun 69	1620	2230	1		33	WC1
	5 Jun 72	1915	0200 (2300)			35	WC2
Dead Horse Ck. trib.	3 Jun 72	1340	2100	1		91	WDH1
East Teapot Ck.	10 Jun 65	1420	1920	1		104	WET1
Dugout Ck. trib.	24 Jun 65	1425	2105	1		111	WD1
Headgate Draw @ upper station	16 Jun 69	1645	2030	1		119	WHD1
Medicine Bow R. trib.	28 Jun 73	1500	2100	1		148	WMB1

17 July 1981

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Water Resources Division
P.O. Box 1125
Cheyenne, Wyo 82001

ANALYSIS OF RUNOFF FROM SMALL DRAINAGE BASINS IN WYOMING

By Gordon S. Craig, Jr., and James G. Rankl

OPEN-FILE REPORT 77-727

(pending publication as U.S. Geological Survey water-supply paper.)

Prepared in cooperation with the
WYOMING HIGHWAY DEPARTMENT and the
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Cheyenne Wyoming

September 1977

Table 9.--Characteristics[1] of 22 basins--continued

Station no.	Station name	A (mi^2)	R_m (ft)	S_B (ft/mi)	$S_{10/85}$ (ft/mi)	C_r	L_m (mi)	P_m (mi)	L_{ca} (mi)	F_m (ft)
06634950	Willow Springs Draw trib. near Hanna	1.98	543	719	161	0.4286	2.39	7.62	1.34	430
06644840	McKenzie Draw trib. near Casper	2.02	346	498	100	.7454	2.19	5.83	1.02	346
06648720	Frank Draw trib. near Orpha	.79	337	414	121	.5130	2.01	4.40	.90	337
06648780	Sage Creek trib. near Orpha	1.38	318	355	94.0	.4194	2.92	6.43	1.50	308
09921680	Mud Spring Hollow near Church Butte near Lyman	8.83	752	608	66.5	.3749	8.11	17.20	5.12	607
		8.57488								

[1] From latest topographic maps available.

Table 9.--Characteristics[1] of 22 basins

Drainage area (A) in square miles (mi^2); maximum relief (R_m) in feet (ft); basin slope (S_B) in feet per feet (ft/ft); main-channel slope ($S_{10/85}$) in feet per feet (ft/ft); circularity ratio (C_r) dimensionless; maximum channel length (L_m) in miles (mi); basin perimeter (P_m) in miles (mi); length to centroid along channel (L_{ca}) in miles (mi); maximum fall in channel (F_m) in feet (ft).

	Station no.	Station name	A (mi^2)	R_m (ft)	S_B (ft/mi)	$S_{10/85}$ (ft/mi)	C_r	L_m (mi)	P_m (mi)	L_{ca} (mi)	F_m (ft)
	06233360	Monument Draw near Hudson	8.23	594	719	59.1	0.4458	7.97	15.23	3.79	519
WCU	06238760	W.F. Dry Cheyenne Creek near Riverton	.69	173	240	76.6	.3898	1.93	4.71	.88	173
WCU	06238780	W.F. Dry Cheyenne Creek trib. near Riverton	1.85	316	356	88.2	.6424	2.39	6.01	1.27	258
	06256670	Badwater Creek trib. near Lysite	5.86	627	483	85.5	.5570	4.85	11.49	1.82	627
	06266320	Gillies Draw trib. near Grass Creek	1.30	375	720	204	.5727	1.35	5.34	.68	325
	06266460	Murphy Draw near Grass Creek	2.32	483	431	106	.4764	3.20	7.82	1.35	423
	06267260	N.P.E.F. Nowater Cr. near Worland	3.77	320	771	71.3	.6315	3.05	8.66	.97	310
	06267270	N.P.E.F. Nowater Cr. trib. near Worland	2.11	338	634	79.7	.5262	3.54	7.10	1.59	322
	06274190	Nowood River trib. #2 near Basin	1.51	405	437	140	.4734	2.73	6.33	1.25	405
	06312910	Dead Horse Cr. trib. near Midwest	1.53	287	847	62.3	.4409	3.28	6.60	1.84	287
	06312920	Dead Horse Cr. trib. #2 near Midwest	1.34	320	922	73.9	.5877	2.25	5.35	1.02	233
	06313050	East Teapot Creek near Edgerton	5.44	430	612	92.9	.6492	2.69	10.26	1.24	380
	06313180	Dugout Creek trib. near Midwest	.71	201	831	97.2	.5868	1.40	3.90	.61	171
	06316480	Headgate Draw near Buffalo	3.32	550	929	102	.5363	3.55	8.82	1.71	390
	06382200	Pritchard Draw near Lance Creek	5.12	436	[2] 618	[3] 92.4	.7996	3.67	9.30	2.53	436
	06631150	Third Sand Cr. near Medicine Bow	10.8	680	609	75.5	.4463	6.27	17.43	3.25	575
WHB	06634910	Medicine Bow R. trib. near Hanna	3.01	504	550	132	.4959	3.79	8.73	1.92	483

[1] From latest topographic maps available.
[2] Estimated, using correlation with Army Map Service (scale: 1:250,000) maps.
[3] From aerial photographs.

REGIONAL FREQUENCY ANALYSIS

Regional analysis deals with extending records in space, as opposed to extending them in time. Regional analysis provides a method for transferring information obtained at gaged sites to an ungaged site, where information is needed. According to Riggs (1973), "multiple regression is directly useful as a regionalization tool because the discharge (or volume) can be related to basin characteristics, leaving residuals that may be considered as due to chance. The regression line averages these residuals. Thus, in one operation, the effects of differing basin characteristics are preserved and the chance variation is averaged."

Basin Characteristics

Basin characteristics, used as independent parameters in the regression analyses, are summarized in table 9 and are defined below. Areas were planimetered from the best available topographic maps. Measurements of length along channel, basin perimeter, or contour lines were obtained by stepping with draftsman's dividers set at a scale interval of 200 feet.

A - Drainage area, in square miles.

R_m - Maximum relief in basin, in feet; the difference in elevation between the channel at the gage and the highest point in the basin, determined from topographic maps.

S_B - Basin slope, in feet per mile, obtained by measuring the lengths (in miles) of all contour lines within the drainage boundary, multiplying by the contour interval in feet, and dividing by the drainage area in square miles. Reasonable accuracy can be obtained on most topographic maps by measuring only the 100-foot contour lines.

$S_{10/85}$ - Main-channel slope, in feet per mile, determined from elevations at points 10 and 85 percent of the distance along the channel from the gaging station to drainage-basin divide.

L_m - Main channel length, in miles, from the gaging station to the drainage-basin divide.

C_r - Circularity ratio, dimensionless; the ratio of basin area to the area of a circle having the same perimeter as the basin.

P_m - Basin perimeter, in miles; the length of the drainage area boundary.

L_{ca} - A measured length in miles along the main-stem channel from the gaging station to the point opposite the centroid of the total drainage area (Chow, 1969).

F_m - Maximum fall in channel, in feet; the total difference in elevation between the channel bottom at the gage and the point where the extended main channel reaches the drainage boundary.

Flood Reconstitution for Wyoming W. Fk. Dry Cheyenne Ck. @ upper station WCU 1

Storm Event 12 June 67

Runoff: depth = .33 inches, Q_p = 168 cfs at t_p = 2.08 hours

$R_{recession}$ = .66 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
441.6	0	1.04	5	D		76		1.95	.63	.64	.06	Ø01	
"	"	"	"	N-1		123		1.63	.46	.59	.09	Ø02	
"	"	"	"	N-2		113		2.51	.30	.63	.06	Ø03	
"	"	"	"	N-3		134	2.25	1.46	.43	.62	.07	Ø04	← best
"	"	"	"	Comp.		121	2.25	2.14	.36	.60	.09	Ø5	

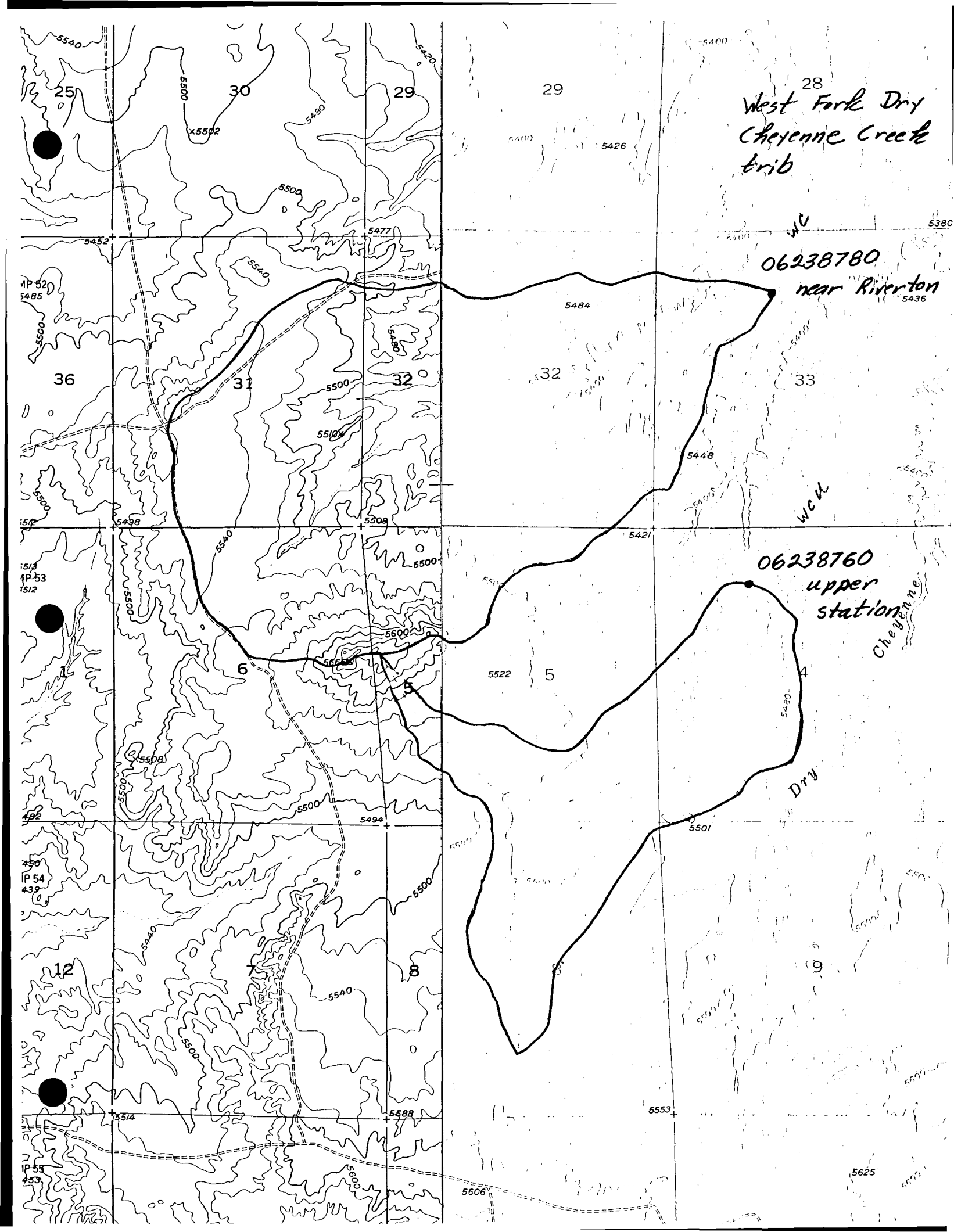
Flood Reconstitution for Wyoming W. Fk. Dry Cheyenne Ck. @ upper station WCU 2

Storm Event 10 June 69

Runoff: depth = .92 inches, Q_p = 275 cfs at t_p = 1.08 hours

$R_{recession}$ = .73 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
441.6	0	1.60	5	D		242	1.25	.72	.84	.41	.15	Ø01	
"	"	"	"	N-3		274	1.17	.49	.73	.48	.11	Ø02	← best
"	"	"	"	N-2		253	1.25	.83	.87	.36	.18	Ø03	
"	"	"	"	N-1		276	1.17	.52	.65	.54	.08	Ø04	
"	"	"	"	Comp.		261	1.25	.69	.80	.43	.14	Ø05	


West Fork Dry Cheyenne Creek trib
06238780 near Riverton
06238760 upper station
Dry Cheyenne
WCU
WCU

WEST FORK DRY CHEYENNE CREEK
AT UPPER STATION
10 JUNE 1969

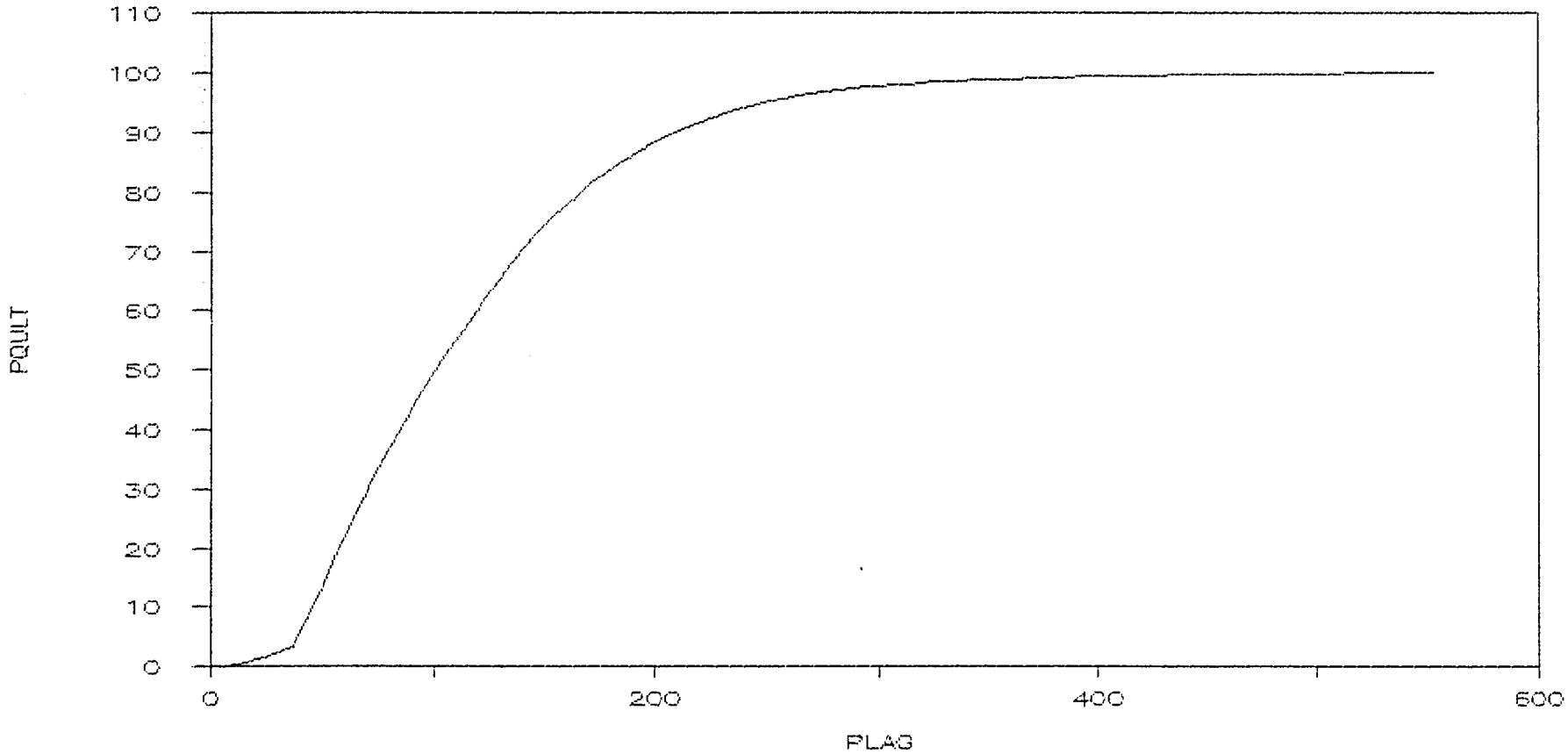
SUM Q	EUD	A	B
4947.60	0.93	2671.69	188.99
LAG	QULT	C	G
1.36	5343.37	0.09	61.55
		q1(F)	q2(E)
		2610.13	2799.12
		t1(H)	t2(X)
		1.33	1.42

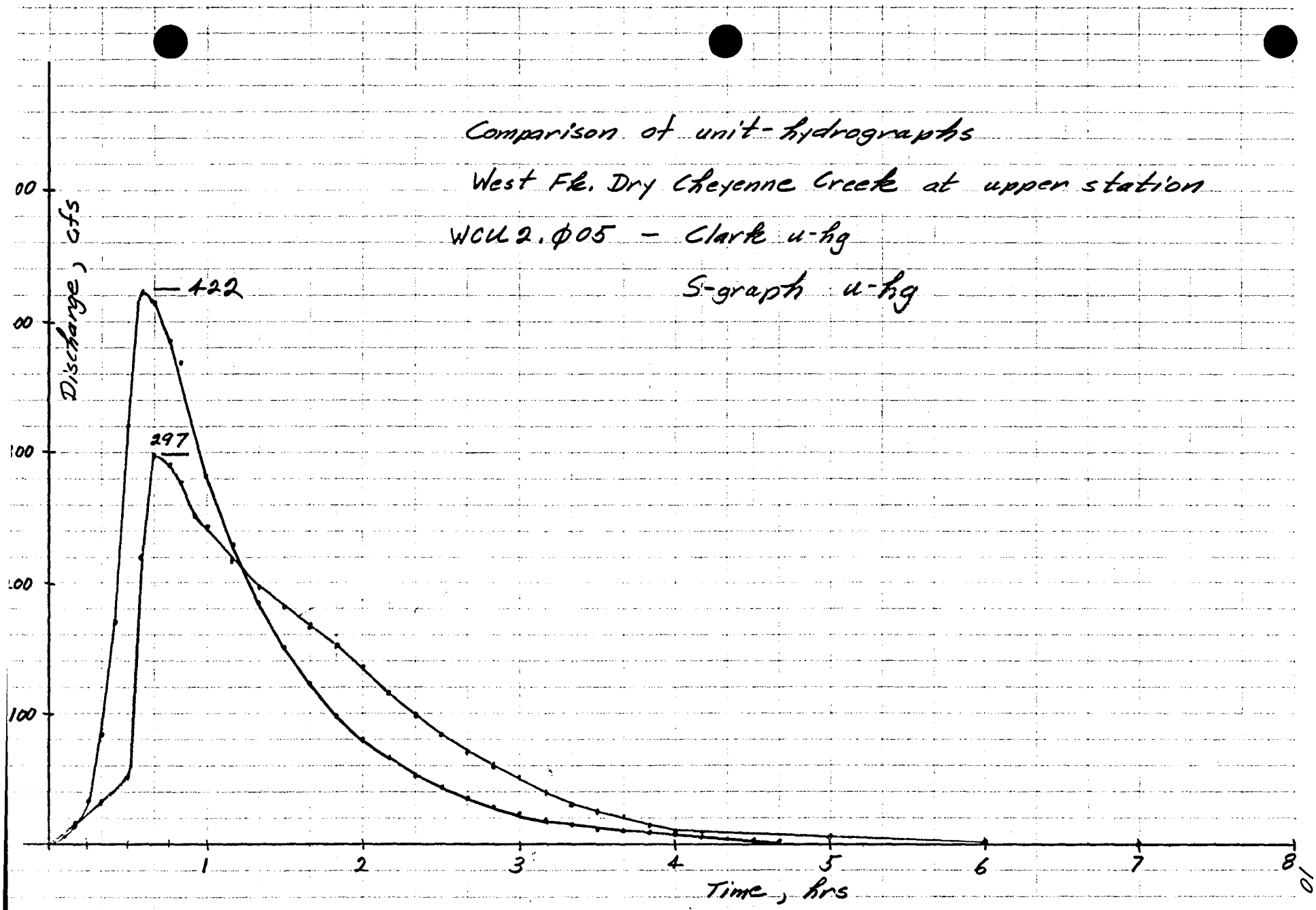
TIME	Q	DEC TI	UHG	SUM UHG	PQULT	PLAG
1535	0.00		0.00	0.00		
1540	0.00		0.00	0.00		
1545	0.00		0.00	0.00		
1550	0.00		0.00	0.00		
1555	0.00		0.00	0.00		
1600	0.00	0.00	0.00	0.00	0.00	0.00
1605	8.80	0.08	9.50	9.50	0.18	5.89
1610	16.00	0.17	17.28	26.78	0.50	12.51
1615	24.00	0.25	25.92	52.70	0.99	18.39
1620	29.00	0.33	31.32	84.02	1.57	24.28
1625	35.00	0.42	37.80	121.82	2.28	30.90
1630	48.00	0.50	51.84	173.66	3.25	36.78
1635	203.00	0.58	219.24	392.90	7.35	42.67
1640	275.00	0.67	297.00	689.90	12.91	49.29
1645	267.00	0.75	288.36	978.26	18.31	55.17
1650	256.00	0.83	276.48	1254.73	23.48	61.06
1655	236.00	0.92	254.88	1509.61	28.25	67.68
1700	226.00	1.00	244.08	1753.69	32.82	73.57
1705	215.00	1.08	232.20	1985.89	37.17	79.45
1710	203.00	1.17	219.24	2205.13	41.27	86.07
1715	193.00	1.25	208.44	2413.57	45.17	91.96
1720	182.00	1.33	196.56	2610.13	48.85	97.84
1725	175.00	1.42	189.00	2799.12	52.38	104.46
1730	168.00	1.50	181.44	2980.56	55.78	110.35
1735	161.00	1.58	173.88	3154.44	59.03	116.48
1740	155.00	1.67	167.40	3321.84	62.17	122.61
1745	148.00	1.75	159.84	3481.68	65.16	128.74
1750	140.00	1.83	151.20	3632.88	67.99	134.87
1755	133.00	1.92	143.64	3776.52	70.68	141.00
1800	125.00	2.00	135.00	3911.52	73.20	147.13
1805	117.00	2.08	126.36	4037.87	75.57	153.26
1810	108.00	2.17	116.64	4154.51	77.75	159.39
1815	100.00	2.25	108.00	4262.51	79.77	165.52
1820	92.00	2.33	99.36	4361.87	81.63	171.66
1825	84.00	2.42	90.72	4452.59	83.33	177.79
1830	76.00	2.50	82.08	4534.67	84.87	183.92
1835	71.00	2.58	76.68	4611.35	86.30	190.05
1840	65.00	2.67	70.20	4681.55	87.61	196.18
1845	60.00	2.75	64.80	4746.35	88.83	202.31
1850	55.00	2.83	59.40	4805.75	89.94	208.44
1855	51.00	2.92	55.08	4860.83	90.97	214.57
1900	46.00	3.00	49.68	4910.51	91.90	220.70
1905	41.00	3.08	44.28	4954.79	92.73	226.83
1910	37.00	3.17	39.96	4994.75	93.48	232.96
1915	32.00	3.25	34.56	5029.31	94.12	239.09
1920	29.00	3.33	31.32	5060.63	94.71	245.22
1925	27.00	3.42	29.16	5089.79	95.25	251.35
1930	24.00	3.50	25.92	5115.71	95.74	257.48
1935	21.00	3.58	22.68	5138.39	96.16	263.61

1940	19.00	3.67	20.52	5158.91	96.55	269.74
1945	16.00	3.75	17.28	5176.19	96.87	275.87
1950	14.00	3.83	15.12	5191.31	97.15	282.01
1955	13.00	3.92	14.04	5205.35	97.42	288.14
2000	11.00	4.00	11.88	5217.23	97.64	294.27
2005	10.00	4.08	10.80	5228.03	97.84	300.40
2010	9.00	4.17	9.72	5237.75	98.02	306.53
2015	8.00	4.25	8.64	5246.39	98.18	312.66
2020	7.20	4.33	7.78	5254.16	98.33	318.79
2025	6.40	4.42	6.91	5261.07	98.46	324.92
2030	5.60	4.50	6.05	5267.12	98.57	331.05
2035	5.20	4.58	5.62	5272.74	98.68	337.18
2040	4.80	4.67	5.18	5277.92	98.78	343.31
2045	4.40	4.75	4.75	5282.67	98.86	349.44
2050	4.00	4.83	4.32	5286.99	98.94	355.57
2055	3.60	4.92	3.89	5290.88	99.02	361.70
2100	6.20	5.00	6.70	5297.58	99.14	367.83
2105	3.10	5.08	3.35	5300.93	99.21	373.96
2110	2.90	5.17	3.13	5304.06	99.26	380.09
2115	2.80	5.25	3.02	5307.08	99.32	386.22
2120	2.60	5.33	2.81	5309.89	99.37	392.35
2125	2.50	5.42	2.70	5312.59	99.42	398.49
2130	2.30	5.50	2.48	5315.07	99.47	404.62
2135	2.20	5.58	2.38	5317.45	99.51	410.75
2140	2.00	5.67	2.16	5319.61	99.56	416.88
2145	1.90	5.75	2.05	5321.66	99.59	423.01
2150	1.70	5.83	1.84	5323.50	99.63	429.14
2155	1.60	5.92	1.73	5325.23	99.66	435.27
2200	1.40	6.00	1.51	5326.74	99.69	441.40
2205	1.30	6.08	1.40	5328.14	99.72	447.53
2210	1.30	6.17	1.40	5329.55	99.74	453.66
2215	1.20	6.25	1.30	5330.84	99.77	459.79
2220	1.20	6.33	1.30	5332.14	99.79	465.92
2225	1.10	6.42	1.19	5333.33	99.81	472.05
2230	1.10	6.50	1.19	5334.51	99.83	478.18
2235	1.00	6.58	1.08	5335.59	99.85	484.31
2240	1.00	6.67	1.08	5336.67	99.87	490.44
2245	0.90	6.75	0.97	5337.65	99.89	496.57
2250	0.90	6.83	0.97	5338.62	99.91	502.70
2255	0.80	6.92	0.86	5339.48	99.93	508.84
2300	0.80	7.00	0.86	5340.35	99.94	514.97
2305	0.70	7.08	0.76	5341.10	99.96	521.10
2310	0.60	7.17	0.65	5341.75	99.97	527.23
2315	0.50	7.25	0.54	5342.29	99.98	533.36
2320	0.40	7.33	0.43	5342.72	99.99	539.49
2325	0.30	7.42	0.32	5343.05	99.99	545.62
2330	0.20	7.50	0.22	5343.26	100.00	551.75

W. FK. DRY CHEYENNE CK AT UPPER STATION

10 JUNE 1969




Comparison of unit-hydrographs
West Fk. Dry Cheyenne Creek at upper station
WCU2.Ø05 – Clark u-hg
S-graph u-hg
422
297
Discharge, cfs
Time, hrs
1
2
3
4
5
6
7
8

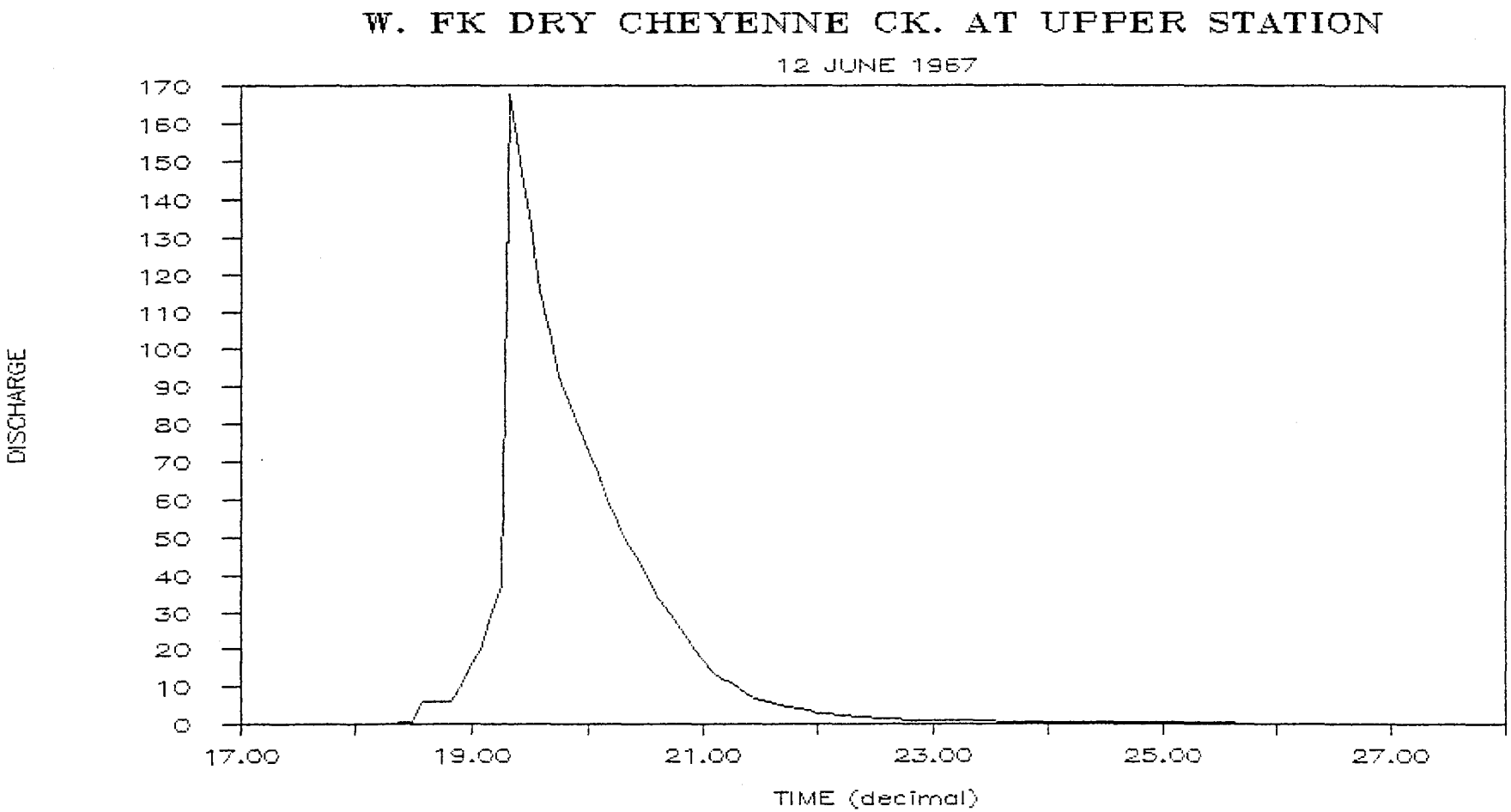
Sept 87

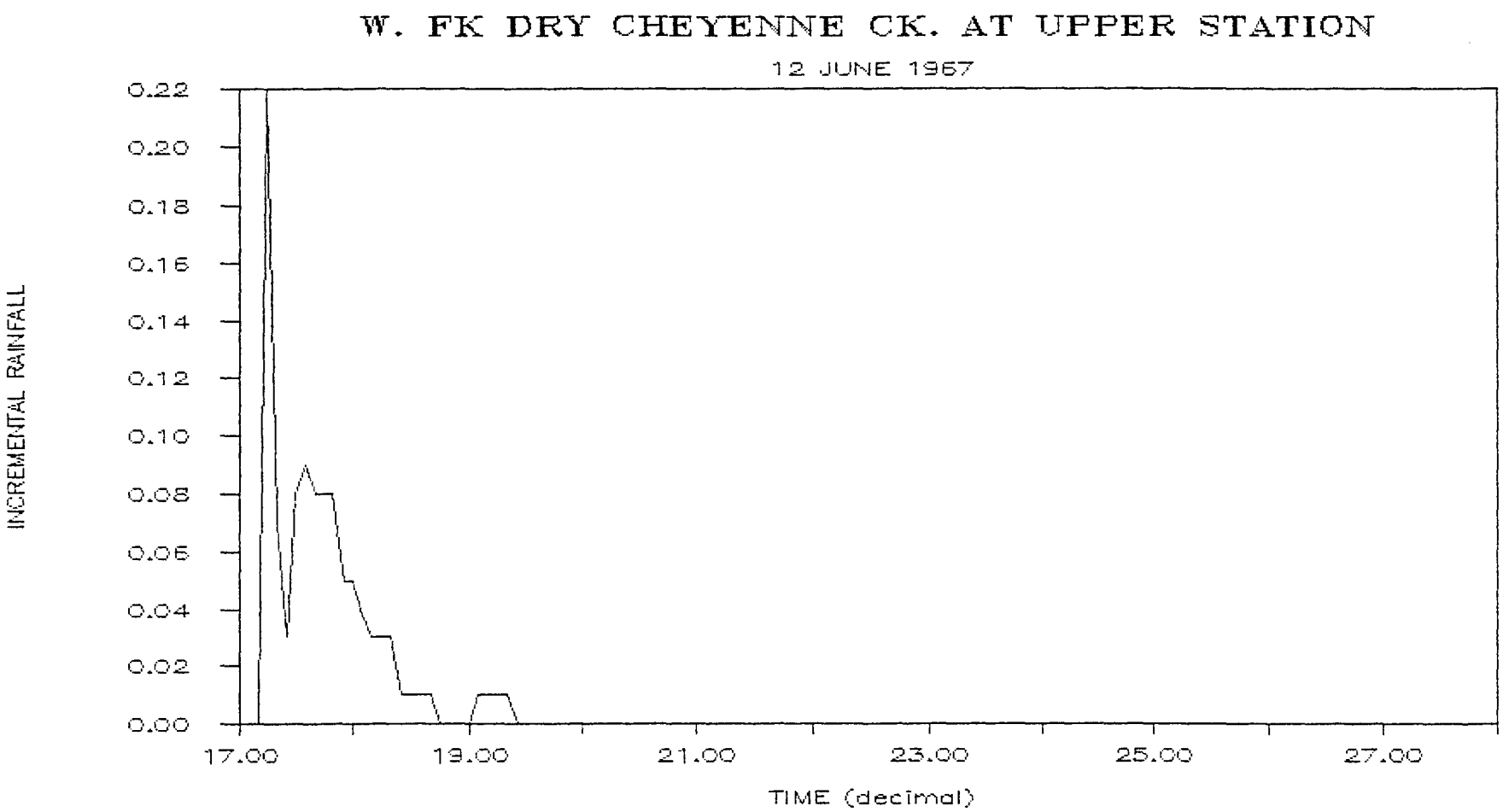
WYOMING DATA
WEST FORK DRY CHEYENNE
AT UPPER STATION
12 JUNE 1967

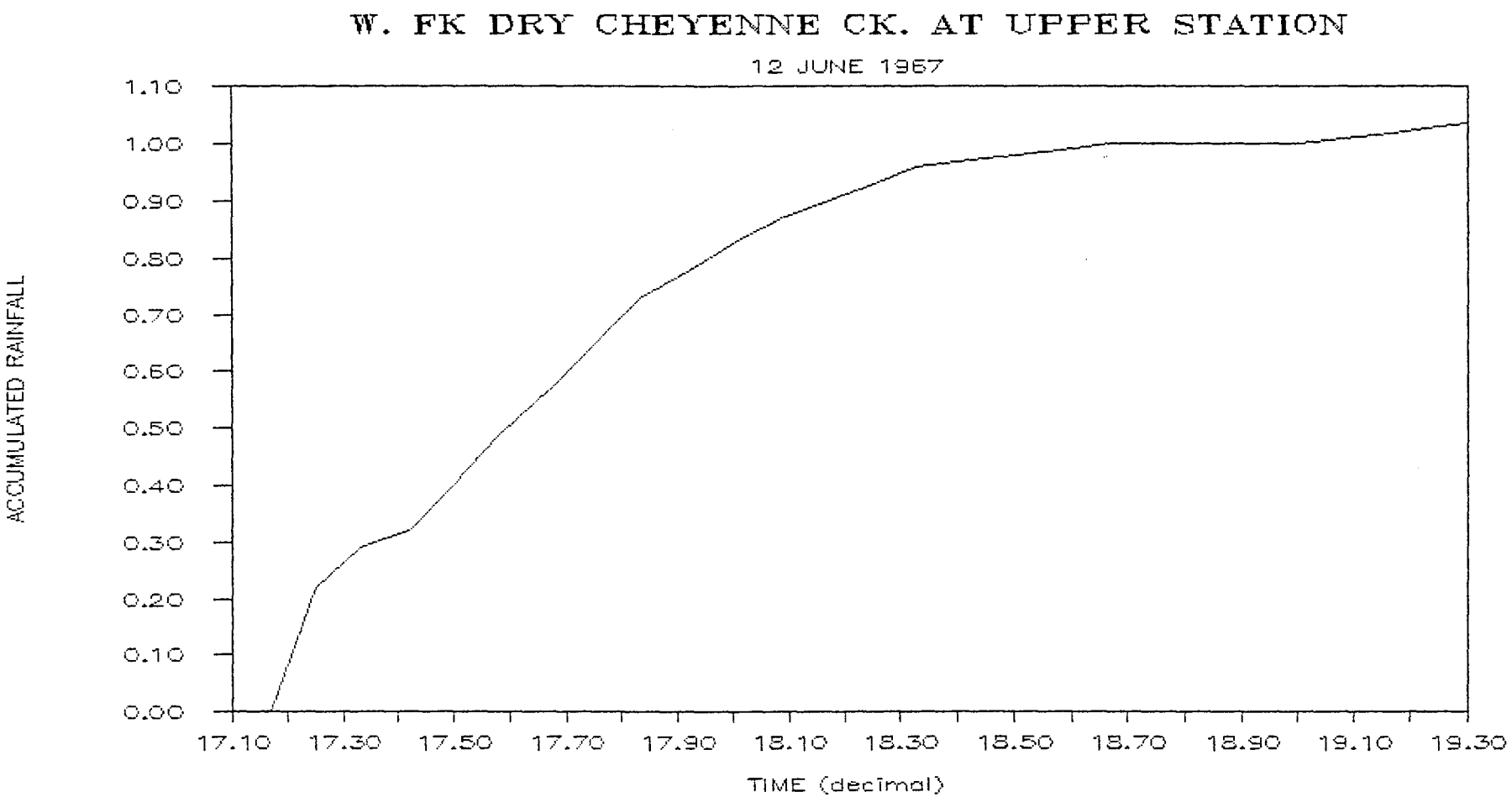
TIME	Q	P1	SUM P1
1710	0.00	0.00	0.00
1715	0.00	0.22	0.22
1720	0.00	0.07	0.29
1725	0.00	0.03	0.32
1730	0.00	0.08	0.40
1735	0.00	0.09	0.49
1740	0.00	0.08	0.57
1745	0.00	0.08	0.65
1750	0.00	0.08	0.73
1755	0.00	0.05	0.78
1760	0.00	0.05	0.83
1800	0.00	0.04	0.87
1805	0.00	0.03	0.90
1810	0.00	0.03	0.93
1815	0.20	0.03	0.96
1820	0.40	0.01	0.97
1825	0.60	0.01	0.98
1830	5.90	0.01	0.99
1835	6.00	0.01	1.00
1840	6.10	0.00	1.00
1845	6.10	0.00	1.00
1850	11.00	0.00	1.00
1855	16.00	0.00	1.00
1900	20.00	0.01	1.01
1905	29.00	0.01	1.02
1910	37.00	0.01	1.03
1915	168.00	0.01	1.04
1920	150.00	0.00	1.04
1925	133.00	0.00	1.04
1930	116.00	0.00	1.04
1935	105.00	0.00	1.04
1940	93.00	0.00	1.04
1945	86.00	0.00	1.04
1950	79.00	0.00	1.04
1955	73.00	0.00	1.04
2000	67.00	0.00	1.04
2005	60.00	0.00	1.04
2010	54.00	0.00	1.04
2015	49.00	0.00	1.04
2020	45.00	0.00	1.04
2025	40.00	0.00	1.04
2030	35.00	0.00	1.04
2035	31.00	0.00	1.04
2040	28.00	0.00	1.04
2045	24.00	0.00	1.04
2050	20.00	0.00	1.04
2055	17.00	0.00	1.04
2100	14.00	0.00	1.04
2105	12.00	0.00	1.04
2110	11.00	0.00	1.04
2115	9.10	0.00	1.04
2120	7.50	0.00	1.04

2125	6.70	0.00	1.04
2130	6.00	0.00	1.04
2135	5.20	0.00	1.04
2140	4.50	0.00	1.04
2145	4.00	0.00	1.04
2150	3.60	0.00	1.04
2155	3.10	0.00	1.04
2200	2.70	0.00	1.04
2205	2.50	0.00	1.04
2210	2.30	0.00	1.04
2215	2.00	0.00	1.04
2220	1.80	0.00	1.04
2225	1.60	0.00	1.04
2230	1.40	0.00	1.04
2235	1.30	0.00	1.04
2240	1.20	0.00	1.04
2245	1.20	0.00	1.04
2250	1.10	0.00	1.04
2255	1.00	0.00	1.04
2300	1.00	0.00	1.04
2305	1.00	0.00	1.04
2310	0.90	0.00	1.04
2315	0.90	0.00	1.04
2320	0.80	0.00	1.04
2325	0.80	0.00	1.04
2330	0.70	0.00	1.04
2335	0.70	0.00	1.04
2340	0.70	0.00	1.04
2345	0.60	0.00	1.04
2350	0.60	0.00	1.04
2355	0.50	0.00	1.04
2400	0.50	0.00	1.04
2405	0.50	0.00	1.04
2410	0.50	0.00	1.04
2415	0.50	0.00	1.04
2420	0.50	0.00	1.04
2425	0.50	0.00	1.04
2430	0.50	0.00	1.04
2435	0.40	0.00	1.04
2440	0.40	0.00	1.04
2445	0.40	0.00	1.04
2450	0.40	0.00	1.04
2455	0.40	0.00	1.04
2500	0.40	0.00	1.04
2505	0.40	0.00	1.04
2510	0.40	0.00	1.04
2515	0.40	0.00	1.04
2520	0.40	0.00	1.04
2525	0.40	0.00	1.04
2530	0.40	0.00	1.04
2535	0.30	0.00	1.04
2540	0.30	0.00	1.04
2545	0.30	0.00	1.04
2550	0.30	0.00	1.04
2555	0.30	0.00	1.04
2600	0.30	0.00	1.04
2605	0.30	0.00	1.04
2610	0.30	0.00	1.04

2615	0.30	0.00	1.04
2620	0.30	0.00	1.04
2625	0.30	0.00	1.04
2630	0.30	0.00	1.04
2635	0.30	0.00	1.04
2640	0.30	0.00	1.04
2645	0.20	0.00	1.04
2650	0.20	0.00	1.04
2655	0.20	0.00	1.04
2700	0.20	0.00	1.04
2705	0.20	0.00	1.04
2710	0.20	0.00	1.04
2715	0.10	0.00	1.04
2720	0.10	0.00	1.04
2725	0.10	0.00	1.04
2730	0.10	0.00	1.04
2735	0.10	0.00	1.04
2740	0.10	0.00	1.04
2745	0.00	0.00	1.04


W. FK DRY CHEYENNE CK. AT UPPER STATION
12 JUNE 1967
DISCHARGE
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
17.00
19.00
21.00
23.00
25.00
27.00
TIME (decimal)

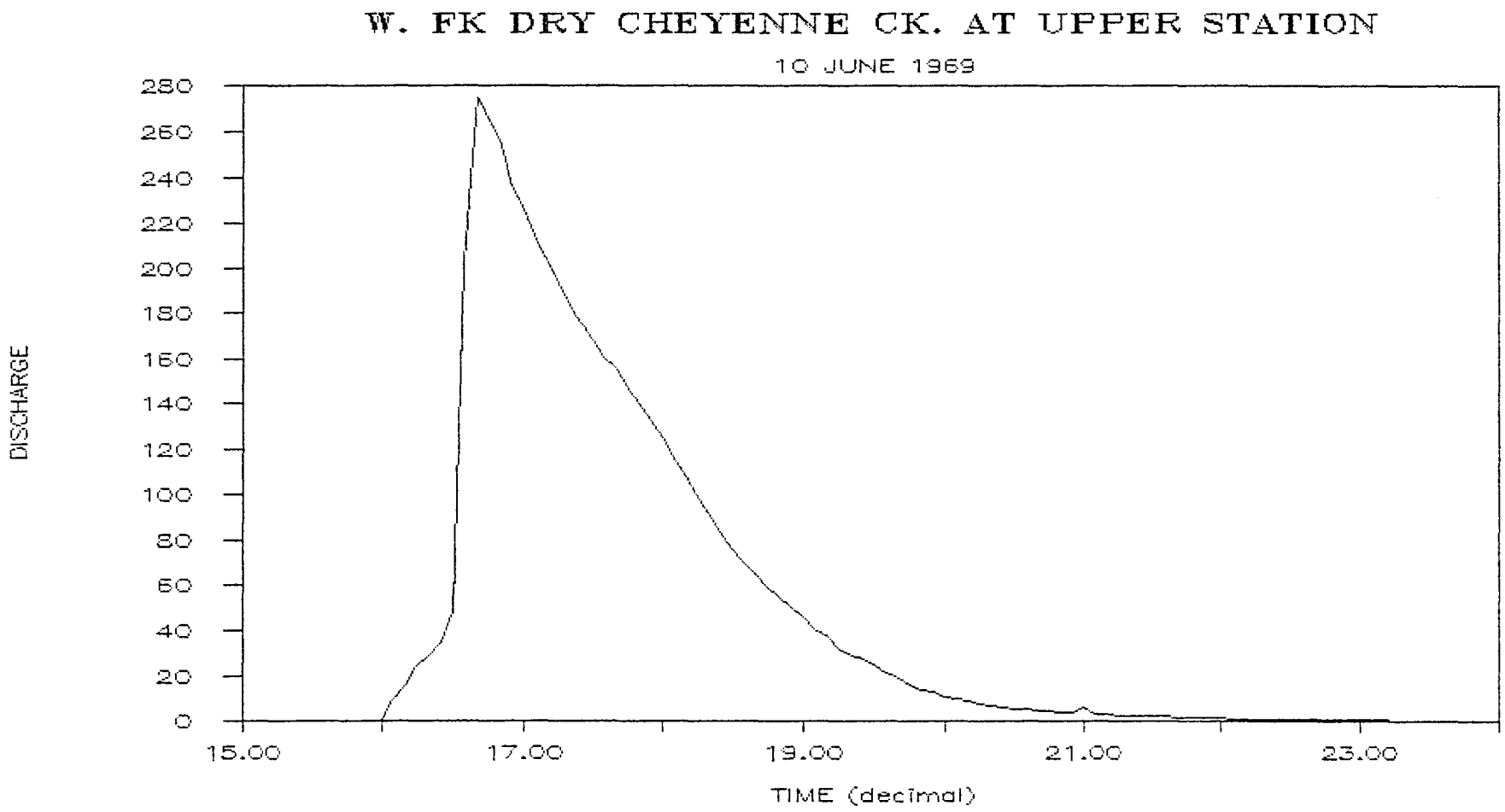

W. FK DRY CHEYENNE CK. AT UPPER STATION
12 JUNE 1967
INCREMENTAL RAINFALL
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
17.00
19.00
21.00
23.00
25.00
27.00
TIME (decimal)

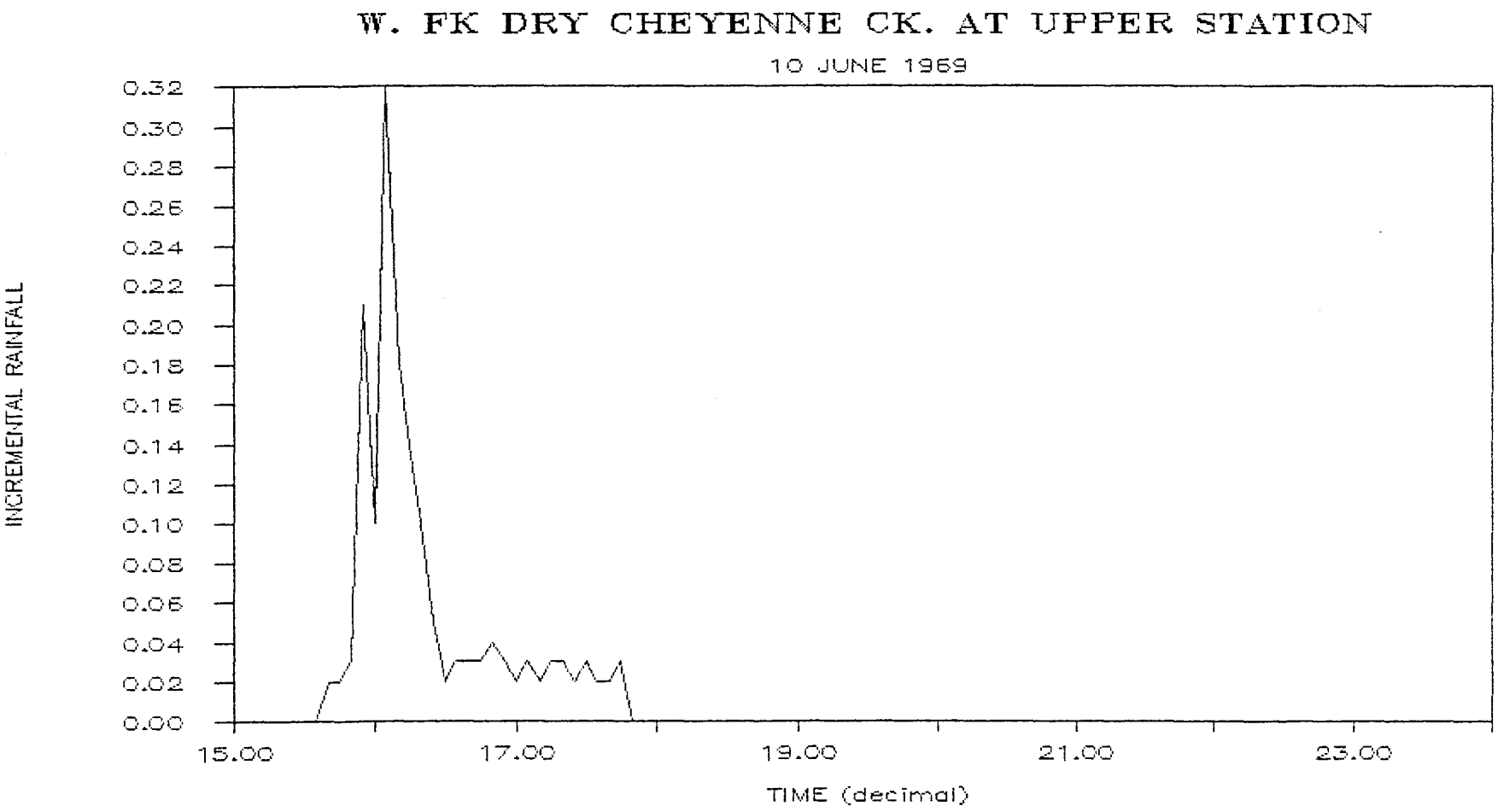

W. FK DRY CHEYENNE CK. AT UPPER STATION
12 JUNE 1967
ACCUMULATED RAINFALL
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
17.10
17.30
17.50
17.70
17.90
18.10
18.30
18.50
18.70
18.90
19.10
19.30
TIME (decimal)

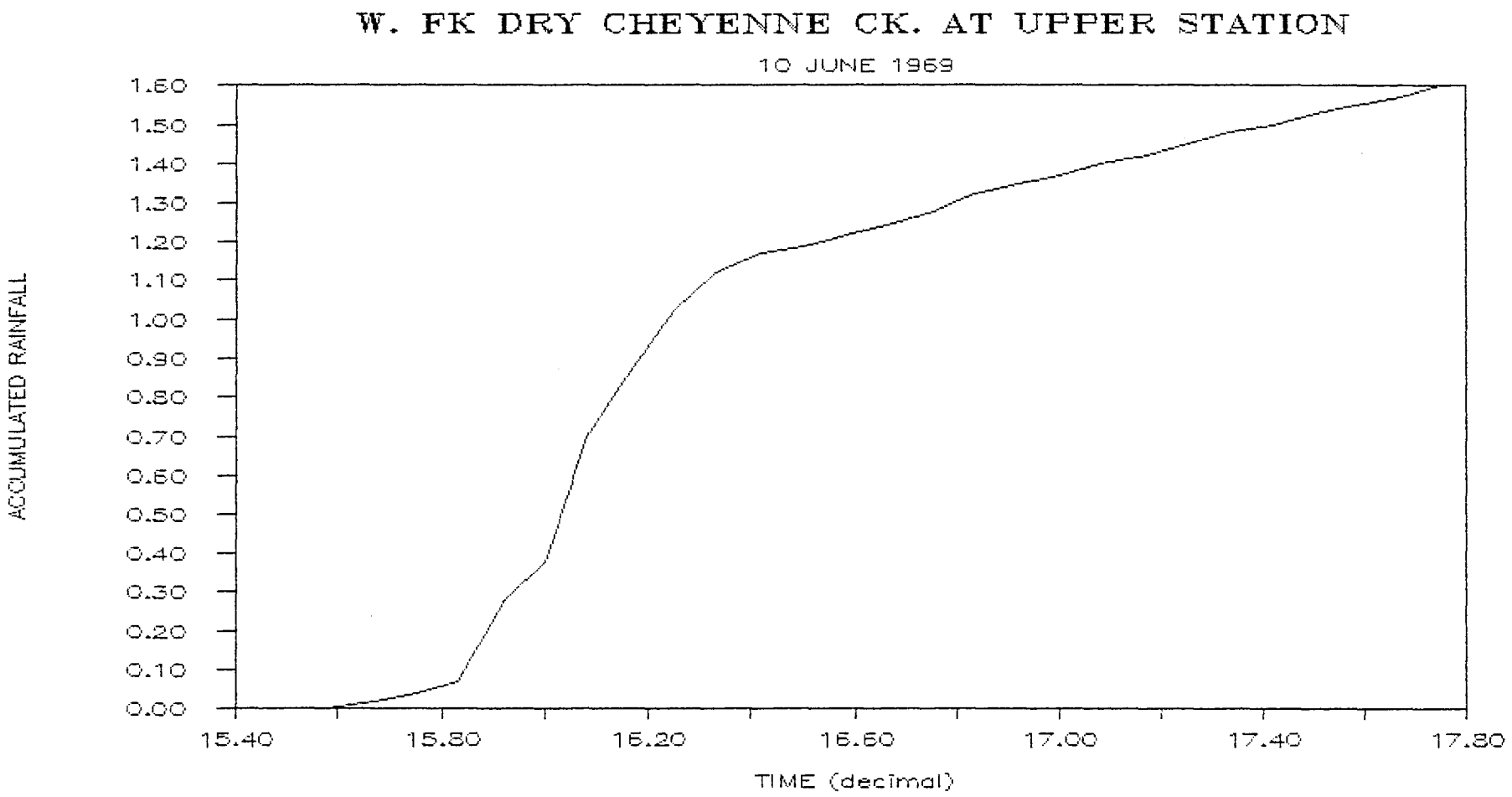
WYOMING DATA
WEST FORK DRY CHEYENNE
AT UPPER STATION
10 JUNE 1969

TIME	Q	P1	SUM P1
1535	0.00	0.00	0.00
1540	0.00	0.02	0.02
1545	0.00	0.02	0.04
1550	0.00	0.03	0.07
1555	0.00	0.21	0.28
1600	0.00	0.10	0.38
1605	8.80	0.32	0.70
1610	16.00	0.18	0.88
1615	24.00	0.14	1.02
1620	29.00	0.10	1.12
1625	35.00	0.05	1.17
1630	48.00	0.02	1.19
1635	203.00	0.03	1.22
1640	275.00	0.03	1.25
1645	267.00	0.03	1.28
1650	256.00	0.04	1.32
1655	236.00	0.03	1.35
1700	226.00	0.02	1.37
1705	215.00	0.03	1.40
1710	203.00	0.02	1.42
1715	193.00	0.03	1.45
1720	182.00	0.03	1.48
1725	175.00	0.02	1.50
1730	168.00	0.03	1.53
1735	161.00	0.02	1.55
1740	155.00	0.02	1.57
1745	148.00	0.03	1.60
1750	140.00	0.00	1.60
1755	133.00	0.00	1.60
1800	125.00	0.00	1.60
1805	117.00	0.00	1.60
1810	108.00	0.00	1.60
1815	100.00	0.00	1.60
1820	92.00	0.00	1.60
1825	84.00	0.00	1.60
1830	76.00	0.00	1.60
1835	71.00	0.00	1.60
1840	65.00	0.00	1.60
1845	60.00	0.00	1.60
1850	55.00	0.00	1.60
1855	51.00	0.00	1.60
1900	46.00	0.00	1.60
1905	41.00	0.00	1.60
1910	37.00	0.00	1.60
1915	32.00	0.00	1.60
1920	29.00	0.00	1.60
1925	27.00	0.00	1.60
1930	24.00	0.00	1.60
1935	21.00	0.00	1.60
1940	19.00	0.00	1.60
1945	16.00	0.00	1.60
1950	14.00	0.00	1.60

1955	13.00	0.00	1.60
2000	11.00	0.00	1.60
2005	10.00	0.00	1.60
2010	9.00	0.00	1.60
2015	8.00	0.00	1.60
2020	7.20	0.00	1.60
2025	6.40	0.00	1.60
2030	5.60	0.00	1.60
2035	5.20	0.00	1.60
2040	4.80	0.00	1.60
2045	4.40	0.00	1.60
2050	4.00	0.00	1.60
2055	3.60	0.00	1.60
2100	6.20	0.00	1.60
2105	3.10	0.00	1.60
2110	2.90	0.00	1.60
2115	2.80	0.00	1.60
2120	2.60	0.00	1.60
2125	2.50	0.00	1.60
2130	2.30	0.00	1.60
2135	2.20	0.00	1.60
2140	2.00	0.00	1.60
2145	1.90	0.00	1.60
2150	1.70	0.00	1.60
2155	1.60	0.00	1.60
2200	1.40	0.00	1.60
2205	1.30	0.00	1.60
2210	1.30	0.00	1.60
2215	1.20	0.00	1.60
2220	1.20	0.00	1.60
2225	1.10	0.00	1.60
2230	1.10	0.00	1.60
2235	1.00	0.00	1.60
2240	1.00	0.00	1.60
2245	0.90	0.00	1.60
2250	0.90	0.00	1.60
2255	0.80	0.00	1.60
2300	0.80	0.00	1.60
2305	0.70	0.00	1.60
2310	0.60	0.00	1.60
2315	0.50	0.00	1.60
2320	0.40	0.00	1.60
2325	0.30	0.00	1.60
2330	0.20	0.00	1.60
2335	0.10	0.00	1.60
2340	0.00	0.00	1.60

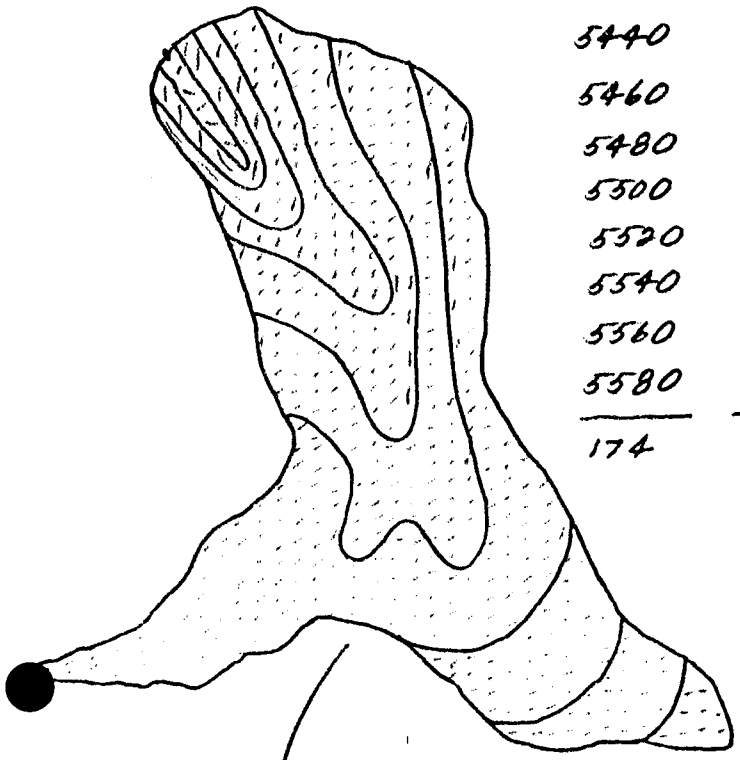

W. FK DRY CHEYENNE CK. AT UPPER STATION
10 JUNE 1969
DISCHARGE
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
15.00
17.00
19.00
21.00
23.00
TIME (decimal)

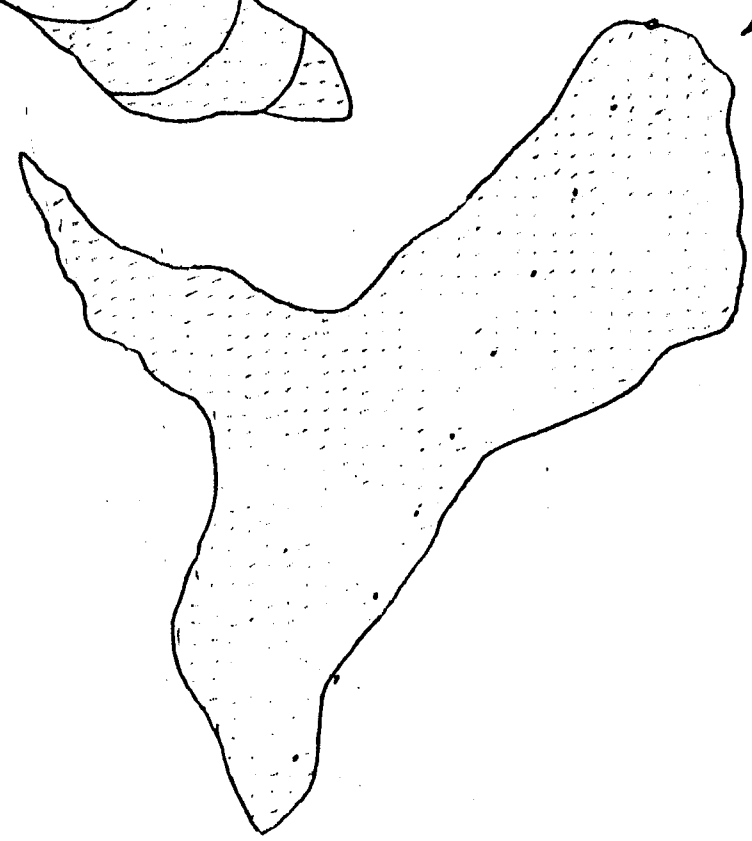

W. FK DRY CHEYENNE CK. AT UPPER STATION
10 JUNE 1969
INCREMENTAL RAINFALL
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
15.00
17.00
19.00
21.00
23.00
TIME (decimal)


W. FK DRY CHEYENNE CK. AT UPPER STATION
10 JUNE 1969
ACCUMULATED RAINFALL
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
15.40
15.80
16.20
16.60
17.00
17.40
17.80
TIME (decimal)

8 Sept 87

	Elevation	Channel Length	Slope
gage	5406		
		1,410	.0099
	5420		
		1,810	.0110
	5440		
		1,810	.0110
	5460		
		1,610	.0124
	5480		
		1,210	.0165
	5500		
		1,010	.0198
	5520		
		1,210	.0165
	5540		
		810	.0247
	5560		
		360	.0556
	5580		
	174	11,240	.0155 avg.

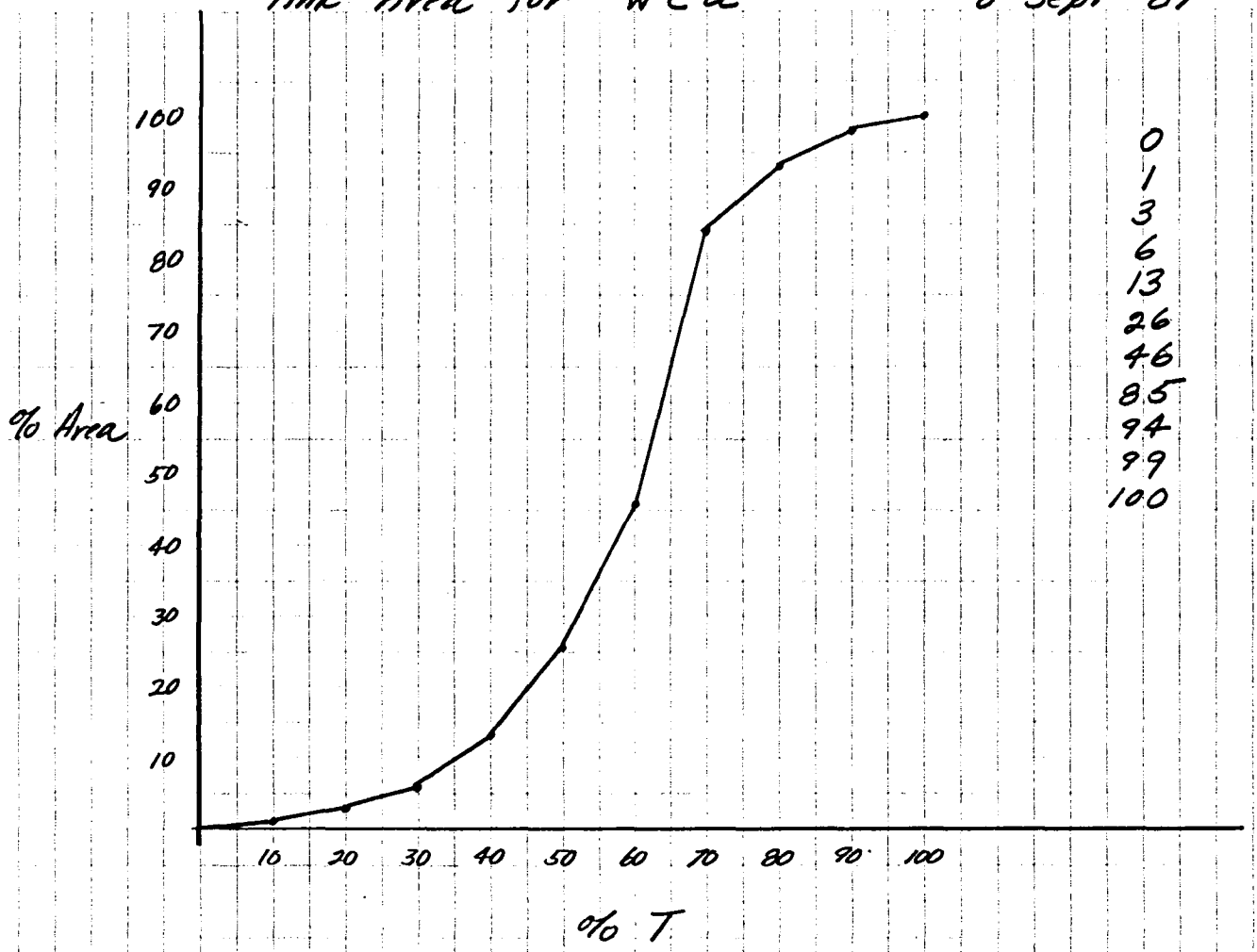




5	1	1
10	2	3
13	3	6
36	7	13
64	13	26
102	20	46
190	38	85
44	9	94
27	5	99
9	1	100
500		

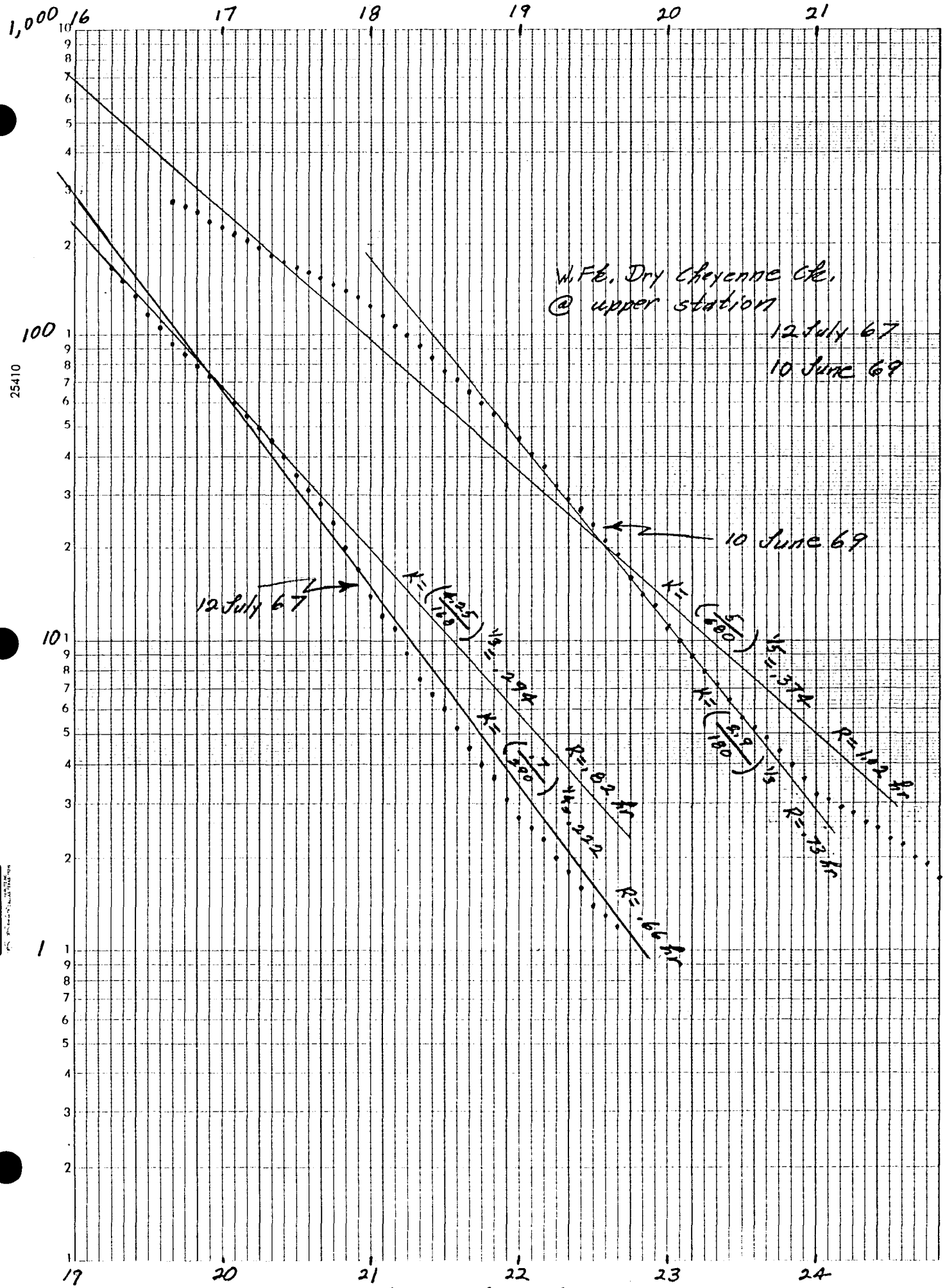
	% area	
		0
26	5	5
50	9	14
65	12	26
67	12	38
62	11	49
70	13	62
102	19	81
48	9	90
38	7	97
16	3	100
544	100	

Time-Area for WCU 8 Sept 87



10 June 69

24 July 81



Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch

12 July 67

25410

college line

Flood Reconstitution for Wyoming W. Fk. Dry Cheyenne trib. near Riverton WC 1

Storm Event 10 June 69

Runoff: depth = .51 inches, Q_p = 421 cfs at t_p = 1.42 hours

$R_{recession}$ = .87 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
1184.	0	1.28	5	D		387	1.67	1.17	.41	.65	.08	Φ01	
"	"	"	"	N-1		429	1.50	.86	.64	.56	.13	Φ02	← best
"	"	"	"	N-3		435	1.50	.77	.66	.56	.13	Φ03	
"	"	"	"	Comp.		398	1.67	1.07	.41	.65	.08	Φ04	
"	"	"	"	Comp.		415	1.58	1.00	.49	.64	.08	Φ05	

Flood Reconstitution for Wyoming W. Fk. Dry Cheyenne trib. near Riverton WC 2

Storm Event 5 June 72

Runoff: depth = 1.21 inches, Q_p = 1260 cfs at t_p = 1.42 hours

$R_{recession}$ = .63 hrs

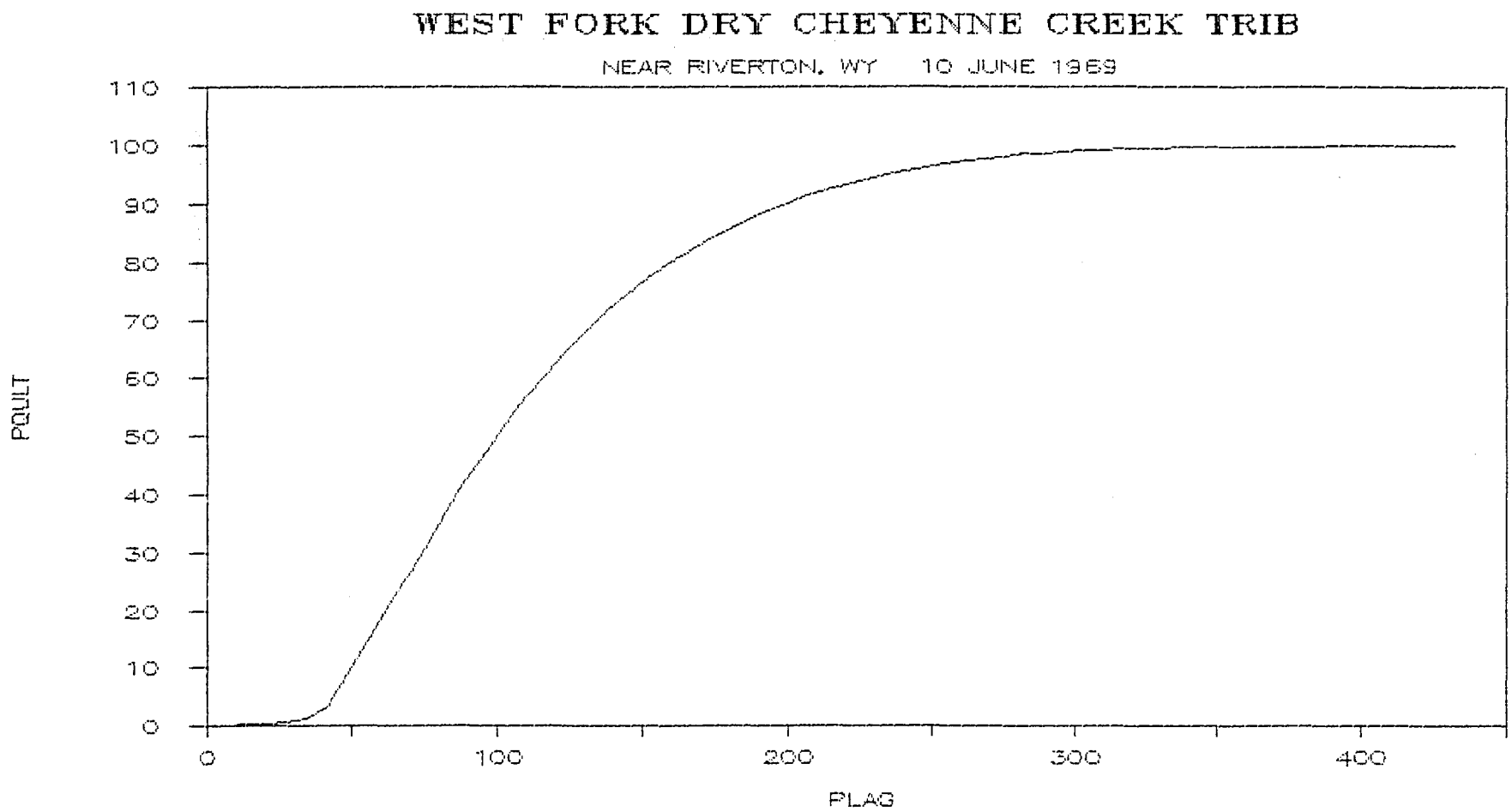
INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
1184.	0	2.34	5	D		1277	1.33	.72	.45	.92	.08	Ø01	
"	"	"	"	N-2		1247	1.33	.73	.66	.68	.21	Ø02	
"	"	"	"	N-1		1233	1.33	.45	.66	.80	.12	Ø03	← selected

WEST FORK DRY CHEYENNE CREEK
TRIB. NEAR RIVERTON, WY
10 JUNE 1969

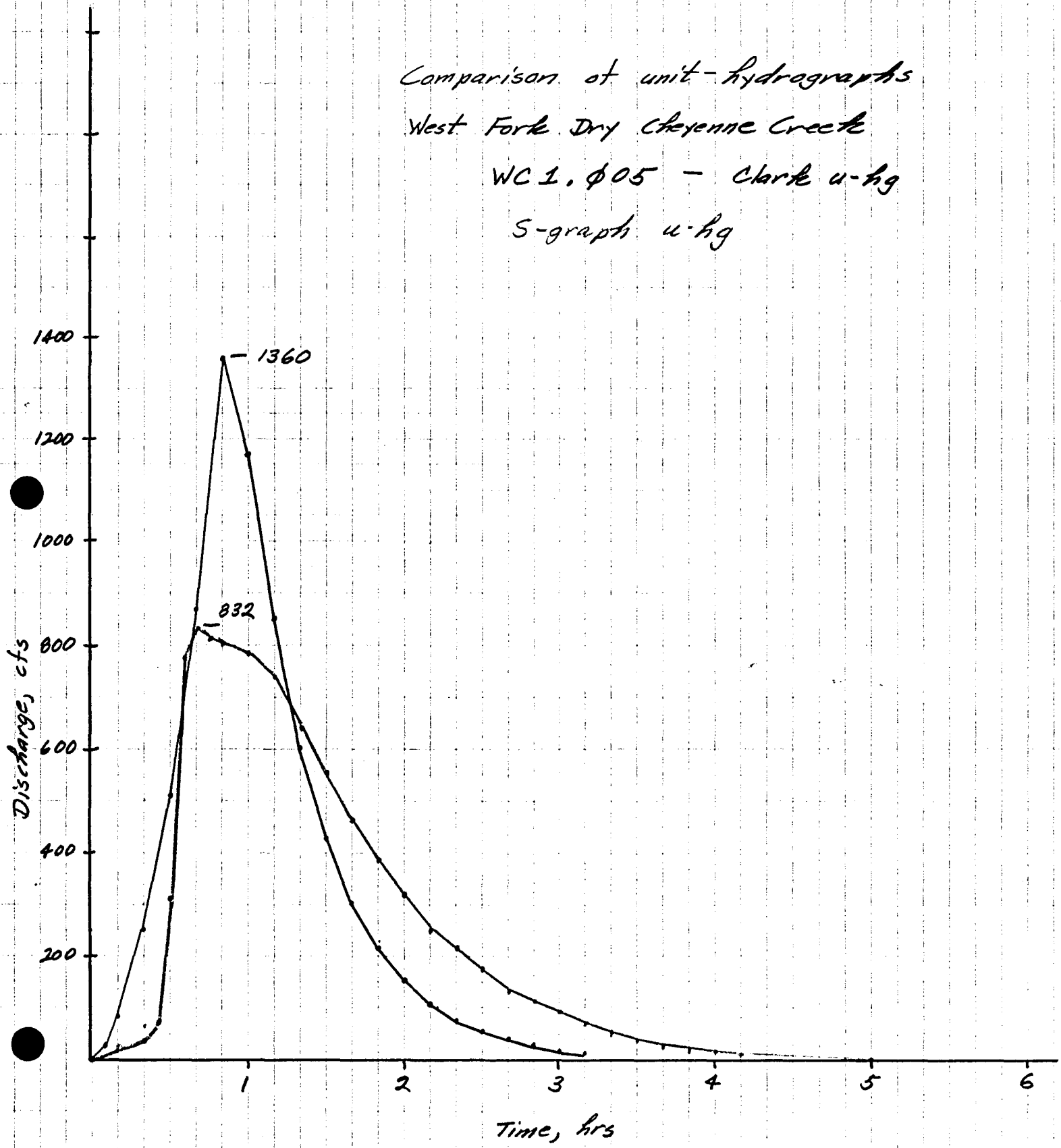
SUM Q	EUD	A	B
7250.60	0.51	7163.22	665.88
LAG	QULT	C	G
1.21	14326.43	0.08	352.31
		q1(F)	q2(E)
		6810.91	7476.79
		t1(H)	t2(X)
		1.17	1.25

TIME	Q	DEC TI	UHG	SUM UHG	PQULT	PLAG
1620	0.00		0.00	0.00		
1625	0.00		0.00	0.00		
1630	0.00		0.00	0.00		
1635	0.00		0.00	0.00		
1640	0.00		0.00	0.00		
1645	0.00		0.00	0.00		
1650	0.00		0.00	0.00		
1655	0.00		0.00	0.00		
1700	0.00		0.00	0.00		
1705	0.00	0.00	0.00	0.00	0.00	0.00
1710	5.00	0.08	9.88	9.88	0.07	6.60
1715	11.00	0.17	21.73	31.61	0.22	14.02
1720	13.00	0.25	25.69	57.30	0.40	20.62
1725	18.00	0.33	35.57	92.87	0.65	27.22
1730	35.00	0.42	69.16	162.02	1.13	34.64
1735	157.00	0.50	310.22	472.24	3.30	41.24
1740	395.00	0.58	780.48	1252.72	8.74	47.84
1745	421.00	0.67	831.85	2084.57	14.55	55.27
1750	411.00	0.75	812.09	2896.66	20.22	61.85
1755	406.00	0.83	802.21	3698.88	25.82	68.46
1800	408.00	0.92	806.17	4505.04	31.45	75.89
1805	399.00	1.00	788.38	5293.42	36.95	82.49
1810	391.00	1.08	772.58	6066.00	42.34	89.08
1815	377.00	1.17	744.91	6810.91	47.54	96.51
1820	337.00	1.25	665.88	7476.79	52.19	103.11
1825	320.00	1.33	632.29	8109.07	56.60	109.71
1830	302.00	1.42	596.72	8705.79	60.77	117.13
1835	280.00	1.50	553.25	9259.04	64.63	123.73
1840	259.00	1.58	511.76	9770.80	68.20	130.60
1845	236.00	1.67	466.31	10237.11	71.46	137.48
1850	214.00	1.75	422.84	10659.95	74.41	144.35
1855	197.00	1.83	389.25	11049.21	77.12	151.22
1900	178.00	1.92	351.71	11400.92	79.58	158.10
1905	161.00	2.00	318.12	11719.03	81.80	164.97
1910	144.00	2.08	284.53	12003.56	83.79	171.85
1915	128.00	2.17	252.91	12256.48	85.55	178.72
1920	119.00	2.25	235.13	12491.61	87.19	185.59
1925	110.00	2.33	217.35	12708.96	88.71	192.47
1930	101.00	2.42	199.57	12908.52	90.10	199.34
1935	91.00	2.50	179.81	13088.33	91.36	206.22
1940	72.00	2.58	142.26	13230.59	92.35	213.09
1945	66.00	2.67	130.41	13361.00	93.26	219.96
1950	62.00	2.75	122.51	13483.51	94.12	226.84
1955	58.00	2.83	114.60	13598.11	94.92	233.71
2000	54.00	2.92	106.70	13704.81	95.66	240.58
2005	47.00	3.00	92.87	13797.68	96.31	247.46
2010	41.00	3.08	81.01	13878.69	96.87	254.33
2015	35.00	3.17	69.16	13947.84	97.36	261.21
2020	30.00	3.25	59.28	14007.12	97.77	268.08

2025	26.00	3.33	51.37	14058.49	98.13	274.95
2030	22.00	3.42	43.47	14101.96	98.43	281.83
2035	19.00	3.50	37.54	14139.51	98.70	288.70
2040	16.00	3.58	31.61	14171.12	98.92	295.57
2045	13.00	3.67	25.69	14196.81	99.10	302.45
2050	11.00	3.75	21.73	14218.54	99.25	309.32
2055	9.00	3.83	17.78	14236.32	99.37	316.20
2100	8.00	3.92	15.81	14252.13	99.48	323.07
2105	7.00	4.00	13.83	14265.96	99.58	329.94
2110	6.00	4.08	11.86	14277.82	99.66	336.82
2115	5.00	4.17	9.88	14287.70	99.73	343.69
2120	4.00	4.25	7.90	14295.60	99.78	350.57
2125	3.00	4.33	5.93	14301.53	99.83	357.44
2130	2.00	4.42	3.95	14305.48	99.85	364.31
2135	1.80	4.50	3.56	14309.04	99.88	371.19
2140	1.60	4.58	3.16	14312.20	99.90	378.06
2145	1.40	4.67	2.77	14314.97	99.92	384.93
2150	1.20	4.75	2.37	14317.34	99.94	391.81
2155	1.10	4.83	2.17	14319.51	99.95	398.68
2200	1.00	4.92	1.98	14321.49	99.97	405.56
2205	0.90	5.00	1.78	14323.26	99.98	412.43
2210	0.70	5.08	1.38	14324.65	99.99	419.30
2215	0.50	5.17	0.99	14325.64	99.99	426.18
2220	0.30	5.25	0.59	14326.23	100.00	433.05


WEST FORK DRY CHEYENNE CREEK TRIB
NEAR RIVERTON, WY 10 JUNE 1969
110
100
90
80
70
60
50
40
30
20
10
0
POULT
0
100
200
300
400
PLAG

10 Sept. 87


Comparison of unit-hydrographs
West Fork Dry Cheyenne Creek
WC 1.05 - Clark u-hg
S-graph u-hg
1360
832
1400
1200
1000
800
600
400
200
Discharge, cfs
1
2
3
4
5
6
Time, hrs

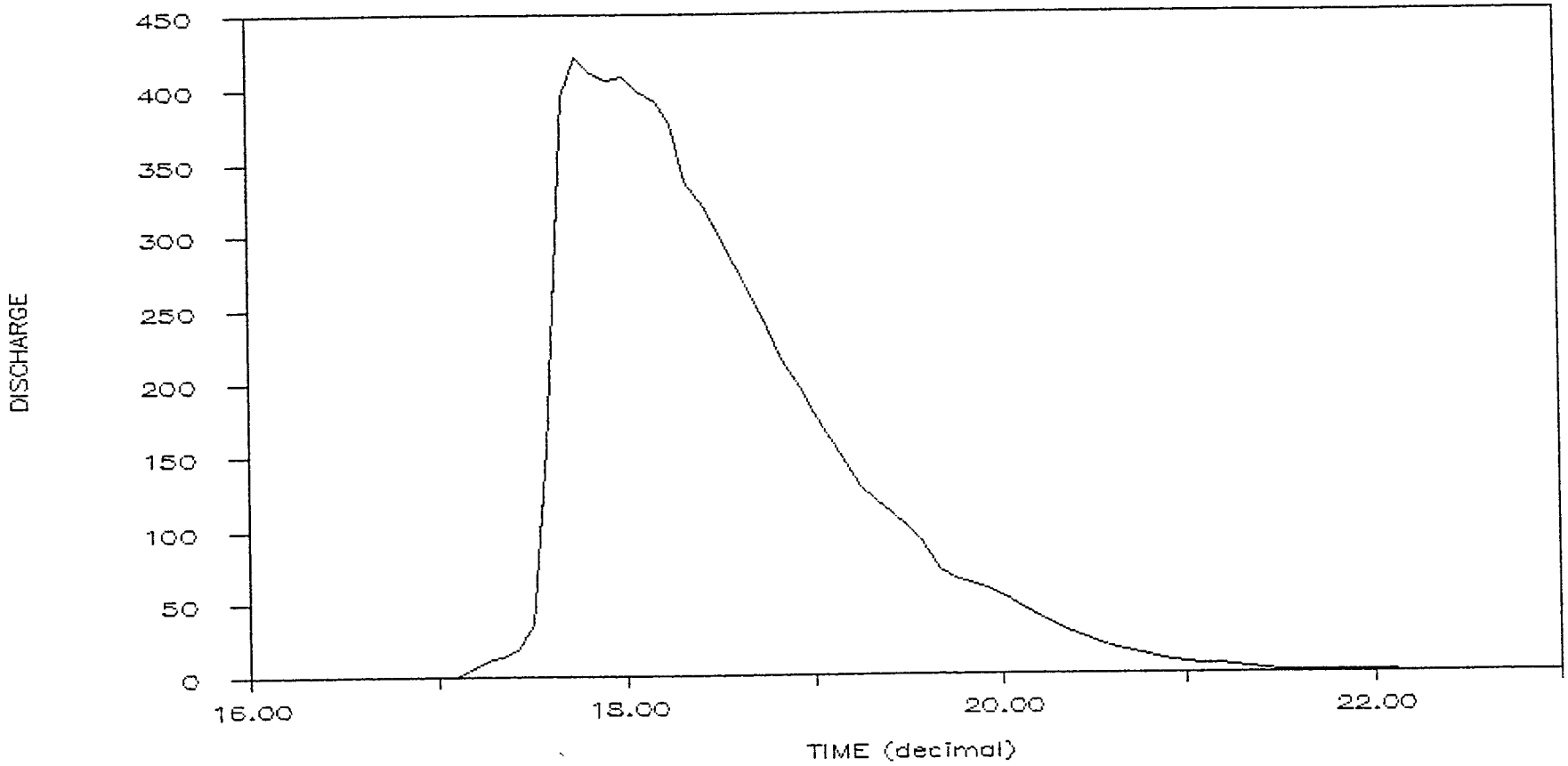
WYOMING DATA
WEST FORK DRY CHEYENNE
TRIB. NEAR RIVERTON
10 JUNE 1969

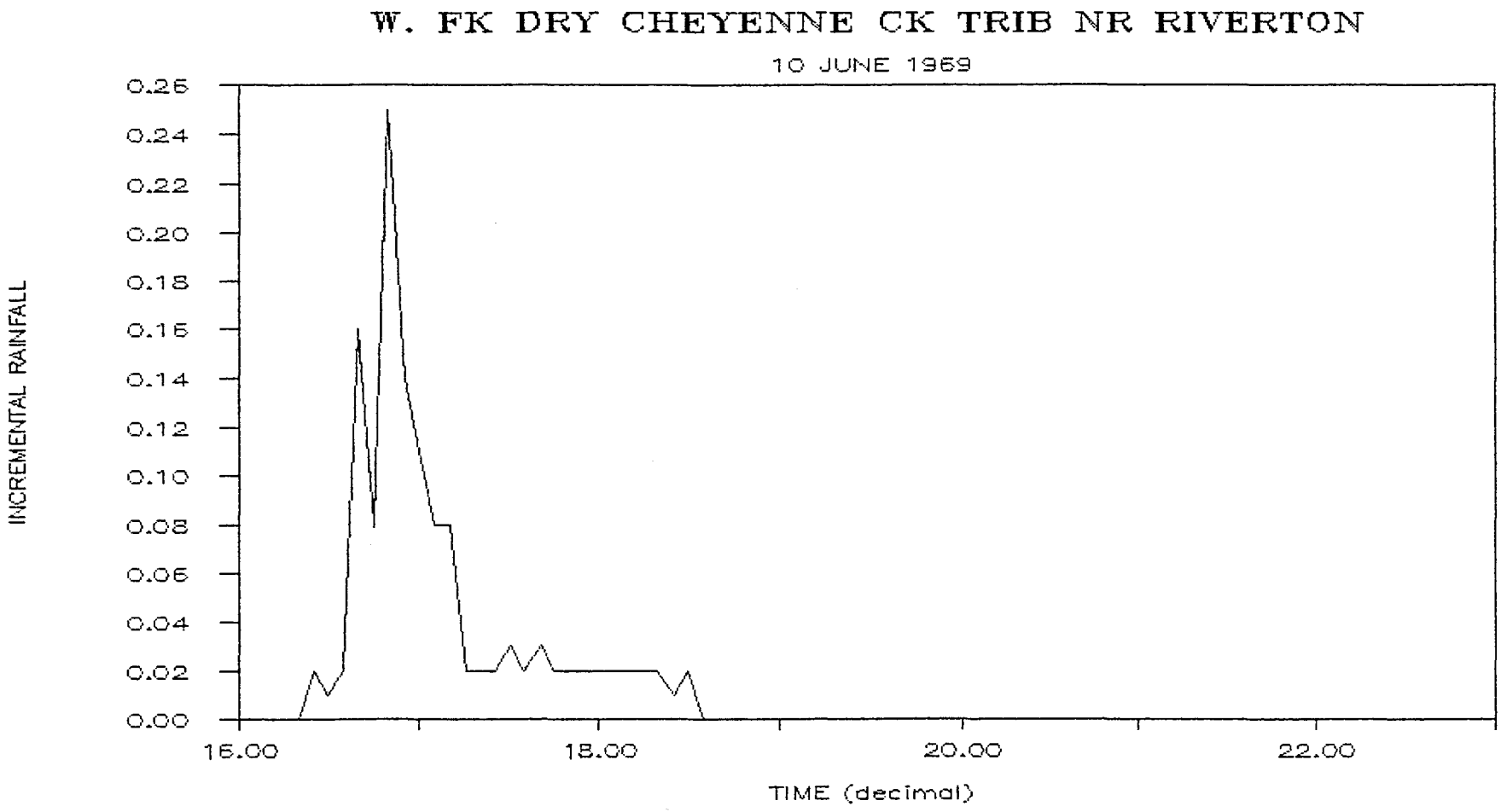
TIME	Q	P1	SUM P1
1620	0.00	0.00	0.00
1625	0.00	0.02	0.02
1630	0.00	0.01	0.03
1635	0.00	0.02	0.05
1640	0.00	0.16	0.21
1645	0.00	0.08	0.29
1650	0.00	0.25	0.54
1655	0.00	0.14	0.68
1700	0.00	0.11	0.79
1705	0.00	0.08	0.87
1710	5.00	0.08	0.95
1715	11.00	0.02	0.97
1720	13.00	0.02	0.99
1725	18.00	0.02	1.01
1730	35.00	0.03	1.04
1735	157.00	0.02	1.06
1740	395.00	0.03	1.09
1745	421.00	0.02	1.11
1750	411.00	0.02	1.13
1755	406.00	0.02	1.15
1800	408.00	0.02	1.17
1805	399.00	0.02	1.19
1810	391.00	0.02	1.21
1815	377.00	0.02	1.23
1820	337.00	0.02	1.25
1825	320.00	0.01	1.26
1830	302.00	0.02	1.28
1835	280.00	0.00	1.28
1840	259.00		1.28
1845	236.00		1.28
1850	214.00		1.28
1855	197.00		1.28
1900	178.00		1.28
1905	161.00		1.28
1910	144.00		1.28
1915	128.00		1.28
1920	119.00		1.28
1925	110.00		1.28
1930	101.00		1.28
1935	91.00		1.28
1940	72.00		1.28
1945	66.00		1.28
1950	62.00		1.28
1955	58.00		1.28
2000	54.00		1.28
2005	47.00		1.28
2010	41.00		1.28
2015	35.00		1.28
2020	30.00		1.28
2025	26.00		1.28
2030	22.00		1.28
2035	19.00		1.28

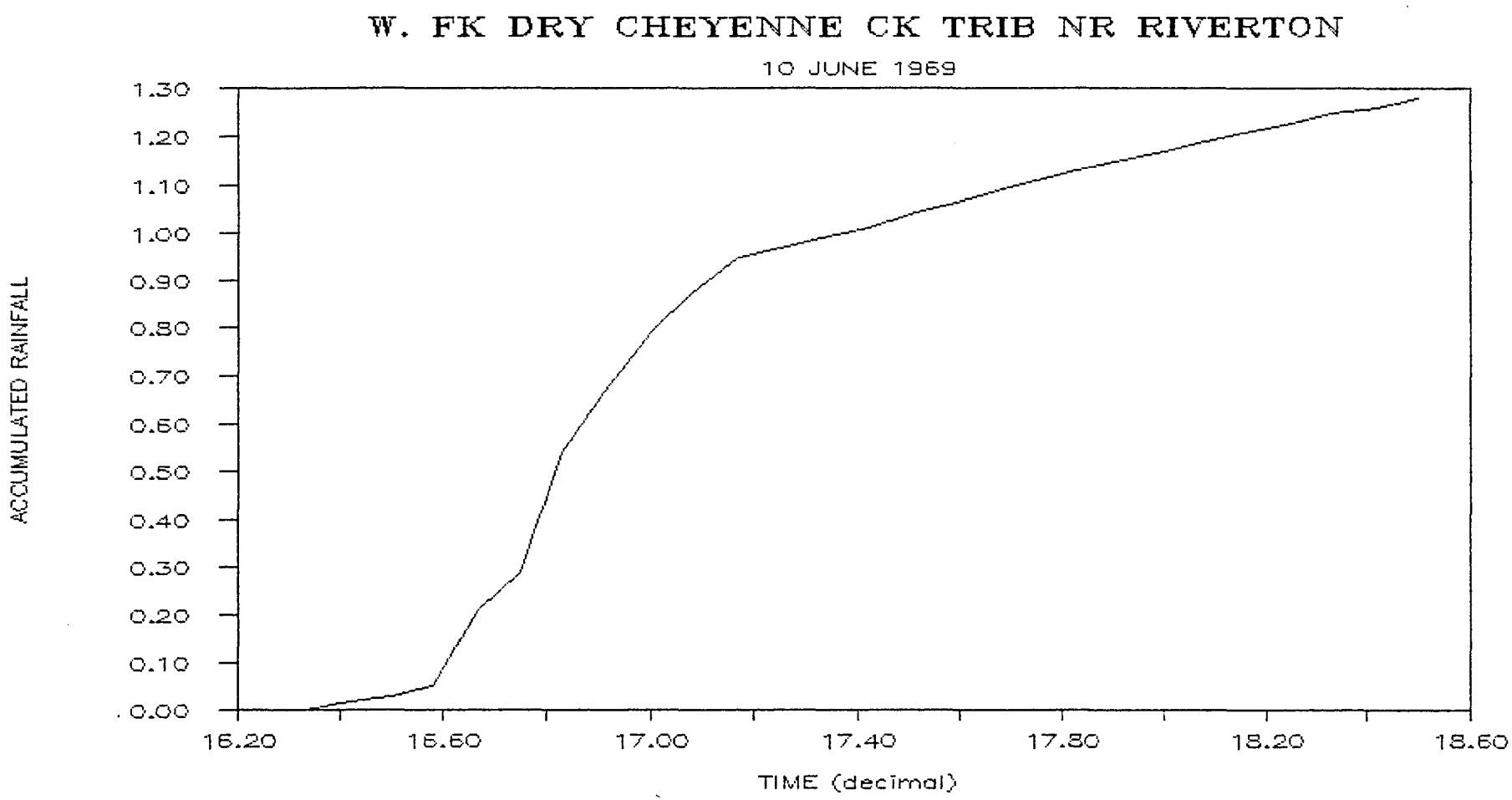
2040	16.00		1.28
2045	13.00		1.28
2050	11.00		1.28
2055	9.00		1.28
2100	8.00		1.28
2105	7.00		1.28
2110	6.00		1.28
2115	5.00		1.28
2120	4.00		1.28
2125	3.00		1.28
2130	2.00		1.28
2135	1.80		1.28
2140	1.60		1.28
2145	1.40		1.28
2150	1.20		1.28
2155	1.10		1.28
2200	1.00		1.28
2205	0.90		1.28
2210	0.70		1.28
2215	0.50		1.28
2220	0.30		1.28
2225	0.10		1.28
2230	0.00	0.0	1.28

W. FK DRY CHEYENNE CK TRIB NR RIVERTON

10 JUNE 1969



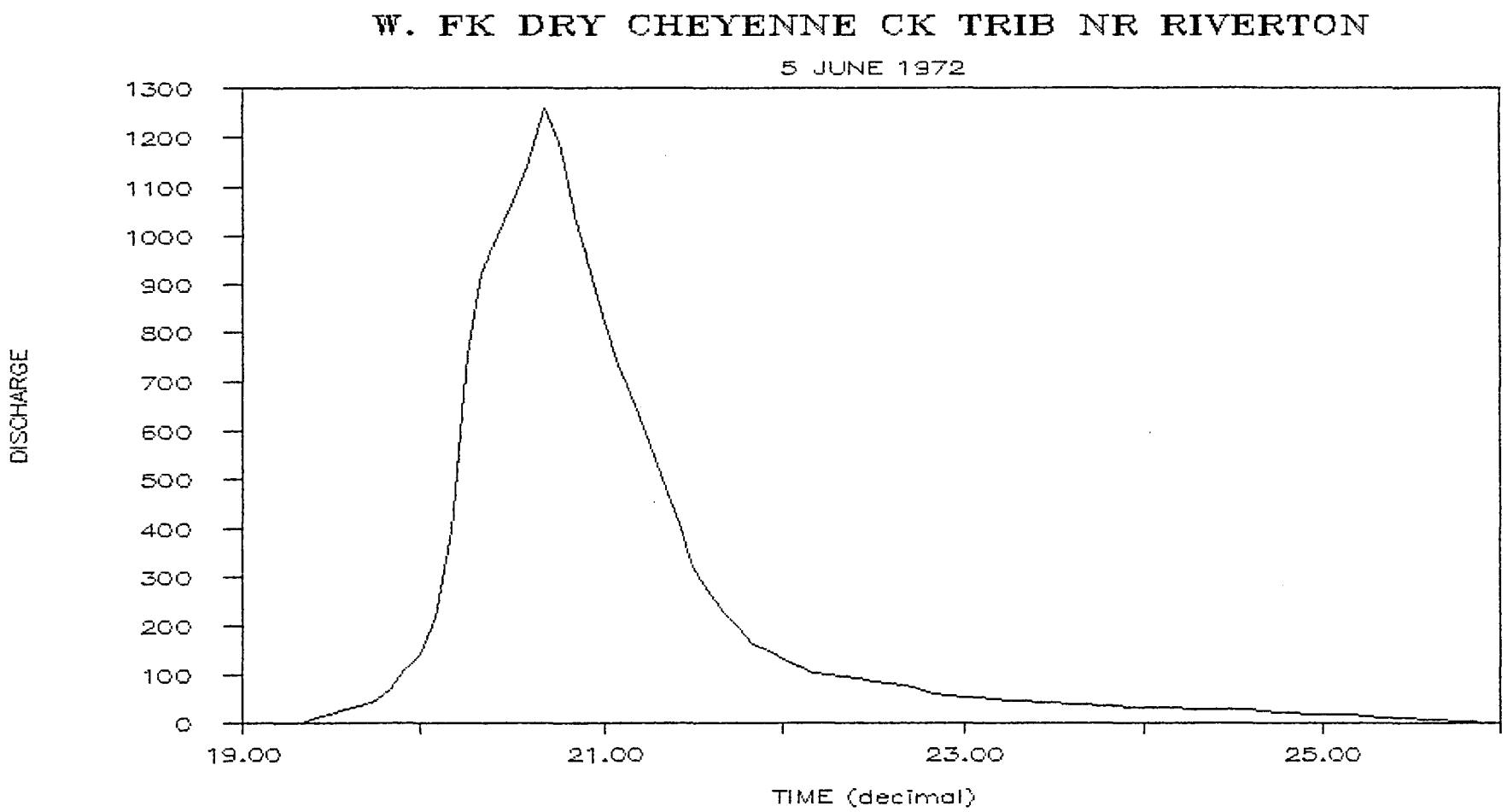

W. FK DRY CHEYENNE CK TRIB NR RIVERTON
10 JUNE 1969
INCREMENTAL RAINFALL
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
16.00
18.00
20.00
22.00
TIME (decimal)

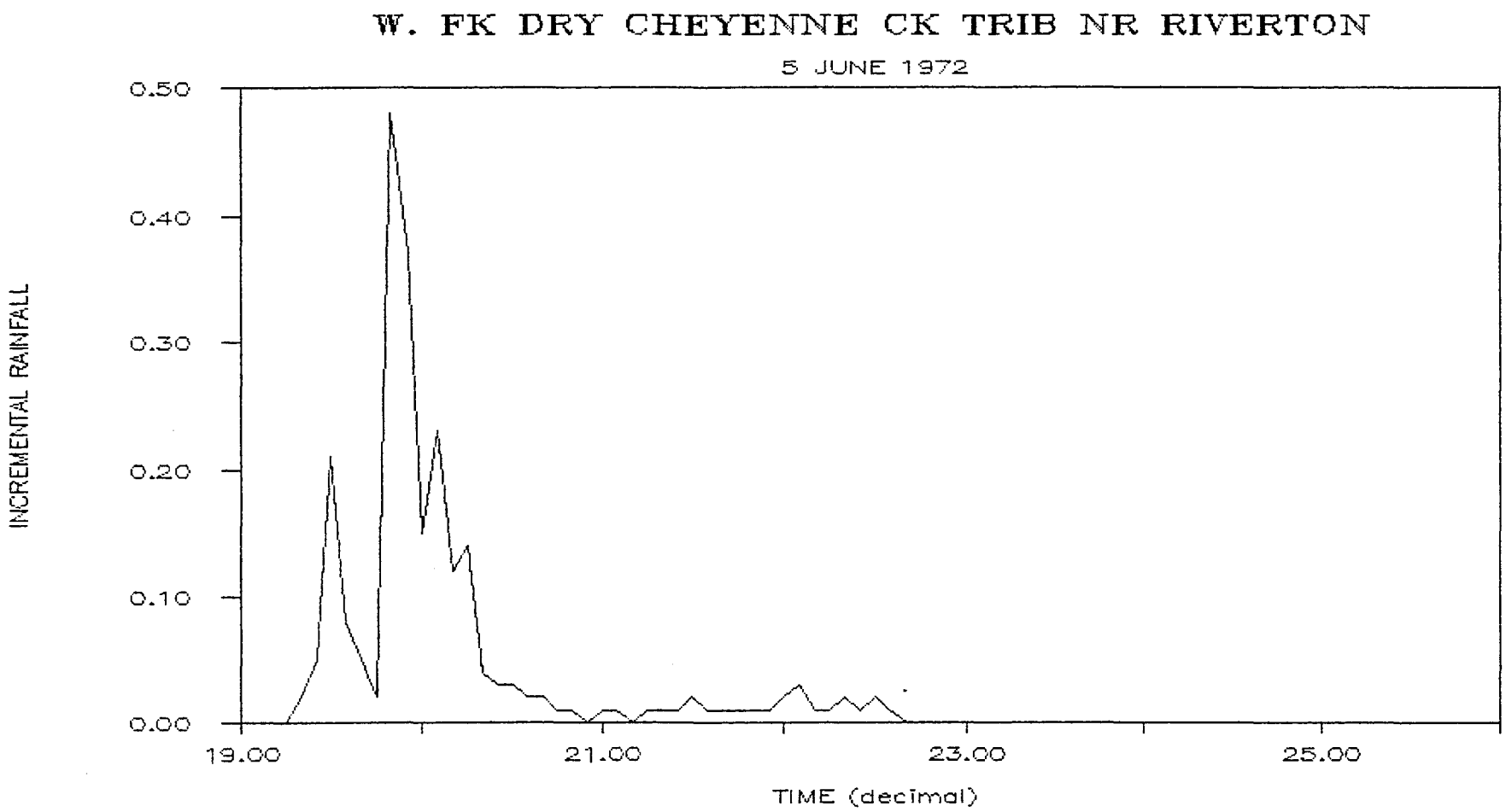

W. FK DRY CHEYENNE CK TRIB NR RIVERTON
10 JUNE 1969
ACCUMULATED RAINFALL
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
16.20
16.60
17.00
17.40
17.80
18.20
18.60
TIME (decimal)

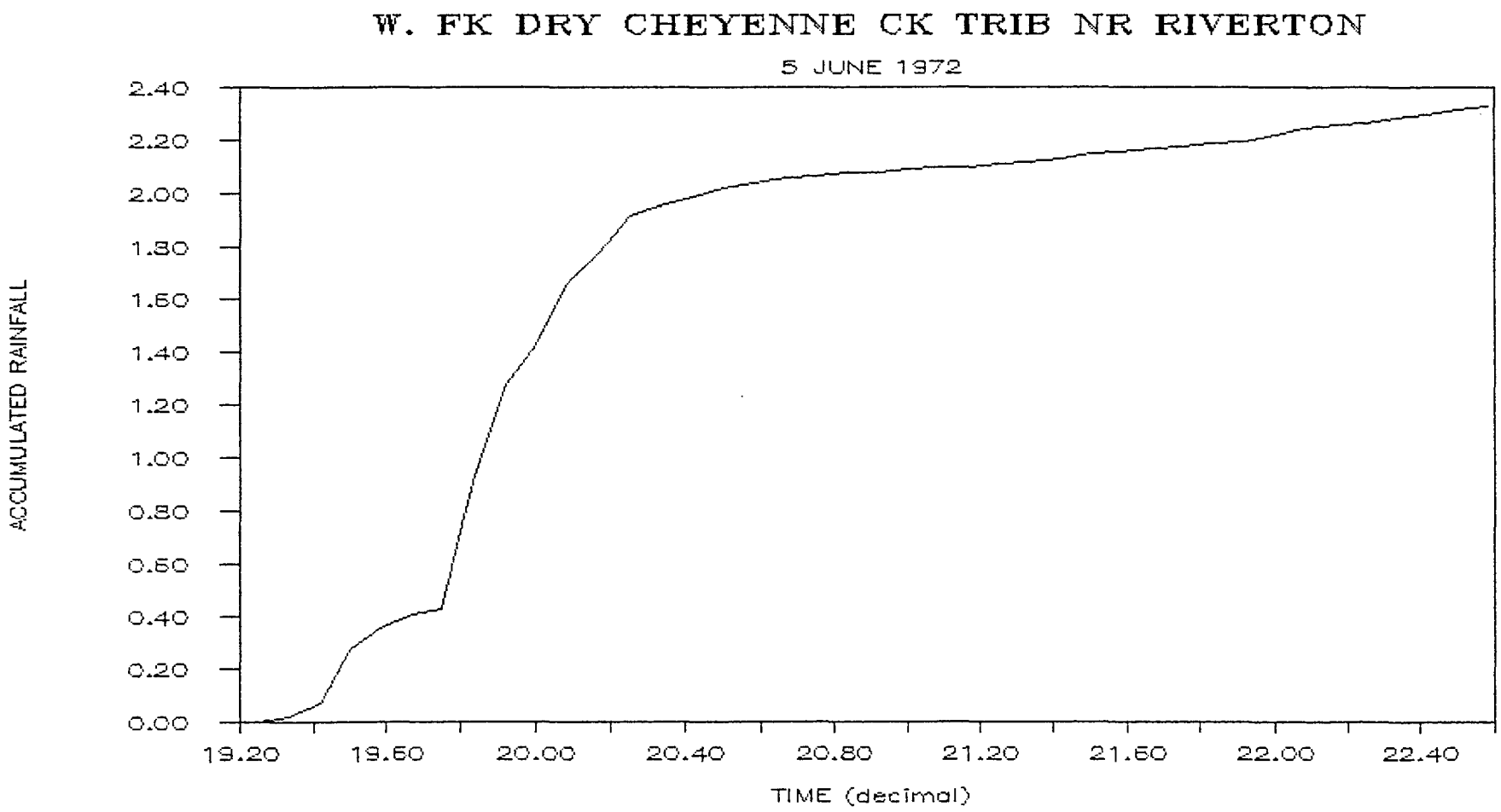
WYOMING DATA
WEST FORK DRY CHEYENNE
TRIB. NEAR RIVERTON
5 JUNE 1972

TIME	Q	P1	SUM P1
1915	0.00	0.00	0.00
1920	0.00	0.02	0.02
1925	10.00	0.05	0.07
1930	19.00	0.21	0.28
1935	28.00	0.08	0.36
1940	35.00	0.05	0.41
1945	47.00	0.02	0.43
1950	69.00	0.48	0.91
1955	112.00	0.37	1.28
2000	142.00	0.15	1.43
2005	216.00	0.23	1.66
2010	394.00	0.12	1.78
2015	755.00	0.14	1.92
2020	920.00	0.04	1.96
2025	1000.00	0.03	1.99
2030	1070.00	0.03	2.02
2035	1140.00	0.02	2.04
2040	1260.00	0.02	2.06
2045	1190.00	0.01	2.07
2050	1040.00	0.01	2.08
2055	937.00	0.00	2.08
2100	821.00	0.01	2.09
2105	736.00	0.01	2.10
2110	652.00	0.00	2.10
2115	576.00	0.01	2.11
2120	500.00	0.01	2.12
2125	411.00	0.01	2.13
2130	322.00	0.02	2.15
2135	275.00	0.01	2.16
2140	228.00	0.01	2.17
2145	195.00	0.01	2.18
2150	163.00	0.01	2.19
2155	147.00	0.01	2.20
2200	131.00	0.02	2.22
2205	117.00	0.03	2.25
2210	103.00	0.01	2.26
2215	100.00	0.01	2.27
2220	96.00	0.02	2.29
2225	91.00	0.01	2.30
2230	86.00	0.02	2.32
2235	82.00	0.01	2.33
2240	78.00	0.00	2.33
2245	70.00	0.00	2.33
2250	62.00	0.00	2.33
2255	58.00	0.00	2.33
2300	55.00	0.00	2.33
2305	52.00	0.00	2.33
2310	49.00	0.00	2.33
2315	47.00	0.00	2.33
2320	46.00	0.00	2.33
2325	44.00	0.00	2.33
2330	43.00	0.00	2.33

2335	40.00	0.00	2.33
2340	38.00	0.00	2.33
2345	36.00	0.00	2.33
2350	34.00	0.00	2.33
2355	33.00	0.00	2.33
2400	32.00	0.00	2.33
2405	31.00	0.00	2.33
2410	31.00	0.00	2.33
2415	30.00	0.00	2.33
2420	30.00	0.00	2.33
2425	29.00	0.00	2.33
2430	28.00	0.00	2.33
2435	27.00	0.00	2.33
2440	25.00	0.00	2.33
2445	23.00	0.00	2.33
2450	21.00	0.00	2.33
2455	20.00	0.00	2.33
2500	19.00	0.00	2.33
2505	18.00	0.00	2.33
2510	17.00	0.00	2.33
2515	15.00	0.00	2.33
2520	13.00	0.00	2.33
2525	11.00	0.00	2.33
2530	10.00	0.00	2.33
2535	9.00	0.00	2.33
2540	7.00	0.00	2.33
2545	5.00	0.00	2.33
2550	3.00	0.00	2.33
2555	1.00	0.00	2.33
2600	0.00	0.00	2.33


W. FK DRY CHEYENNE CK TRIB NR RIVERTON
5 JUNE 1972
DISCHARGE
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
19.00
21.00
23.00
25.00
TIME (decimal)


W. FK DRY CHEYENNE CK TRIB NR RIVERTON
5 JUNE 1972
INCREMENTAL RAINFALL
0.50
0.40
0.30
0.20
0.10
0.00
19.00
21.00
23.00
25.00
TIME (decimal)


W. FK DRY CHEYENNE CK TRIB NR RIVERTON
5 JUNE 1972
ACCUMULATED RAINFALL
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
19.20
19.60
20.00
20.40
20.80
21.20
21.60
22.00
22.40
TIME (decimal)

WC

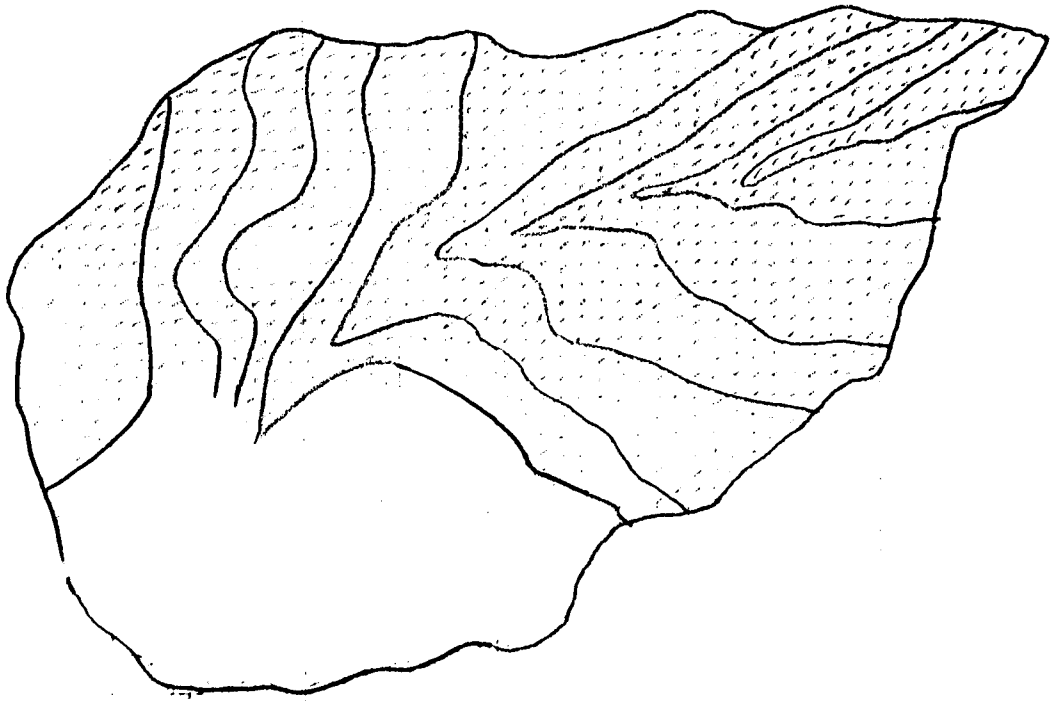
8 Sept. 87

elev. of gage – 5,352.
elev. @ conc. pt. – 5,538.) 186 ft

max. elev. – 5,666.

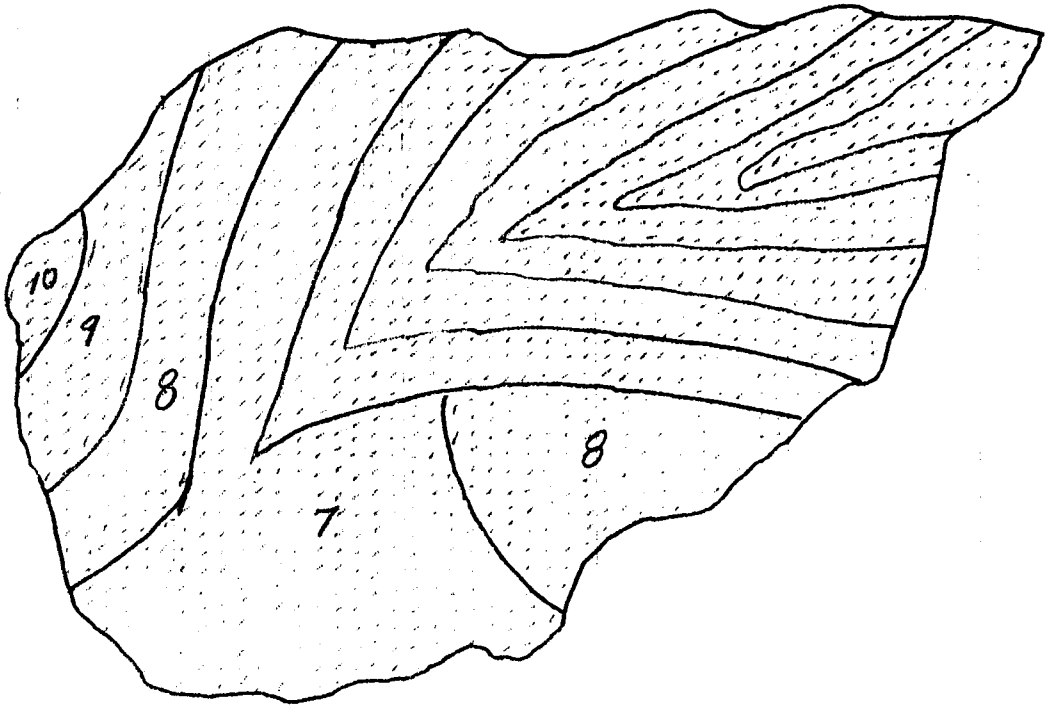
length of channel to conc. pt. = 12,495 ft
avg. channel slope – .0149 ft/ft

WCI.Ø04



		% area
		0
29	29	2
62	91	8
116	207	18
125	332	28
170	502	43
125	627	53
259	886	75
84	970	82
110	1080	92
101	1181	100

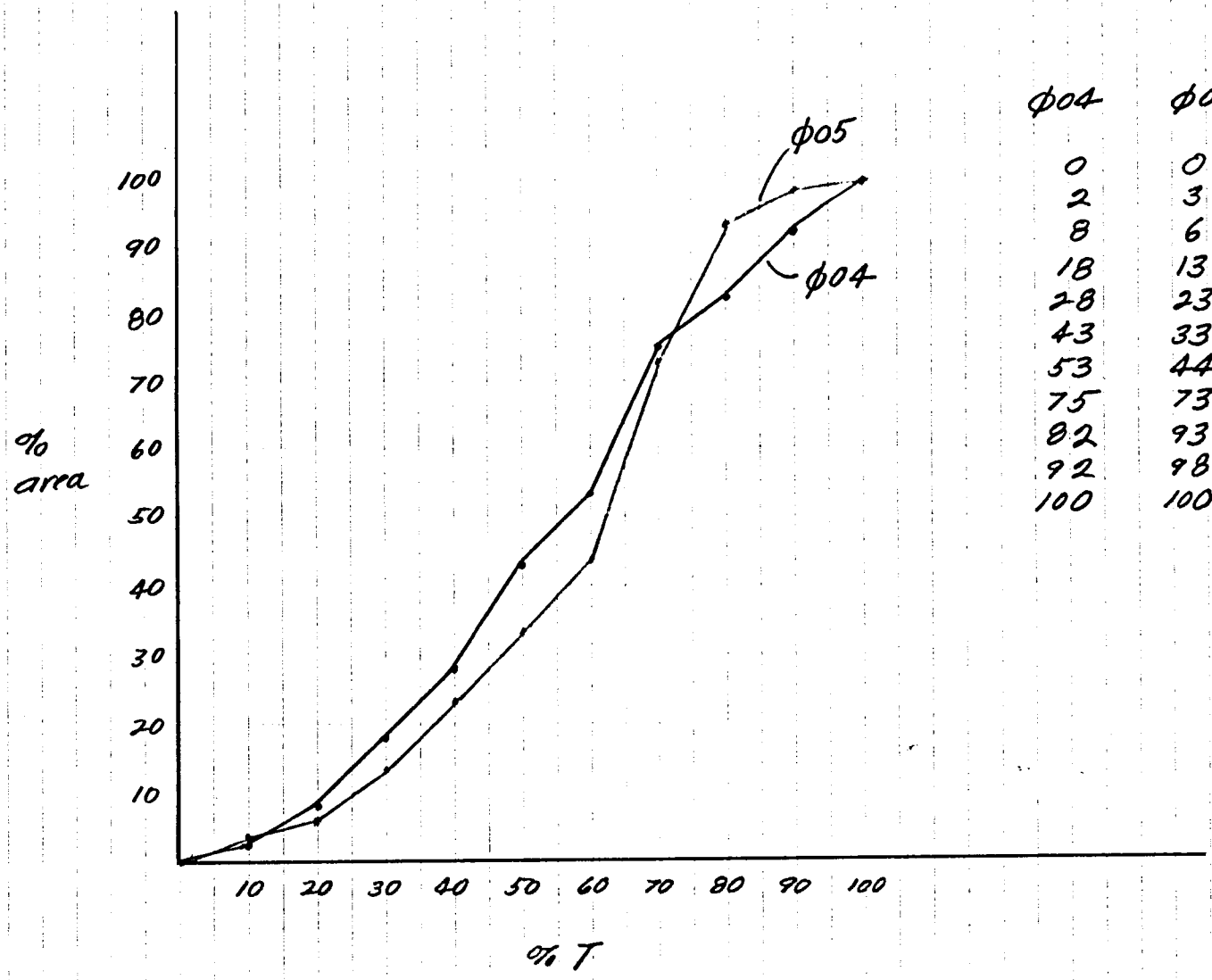
WCI.Ø05



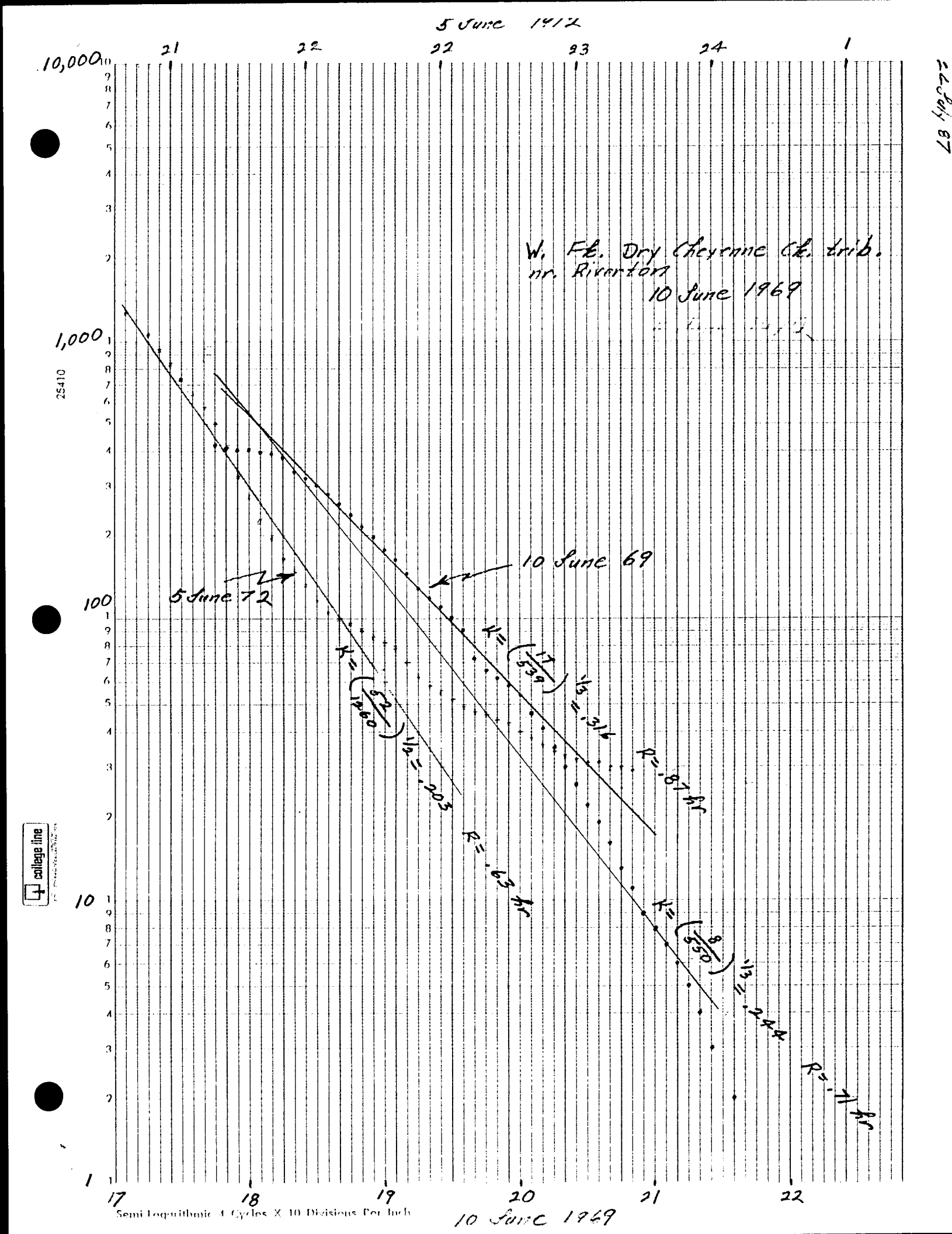
		0
35	35	3
42	77	6
81	158	13
112	270	23
125	395	33
136	531	44
337	868	73
244	1,112	93
67	1,179	98
18	1,197	100

Time-Area for WC

8 Sept. 87



ϕ04	ϕ05
0	0
2	3
8	6
18	13
28	23
43	33
53	44
75	73
82	93
92	98
100	100


5 June 1972
21
22
22
23
24
1
10,000
1,000
100
10
1
17
18
19
20
21
22
W. Fk. Dry Cheyenne Ck. trib.
nr. Riverton
10 June 1969
10 June 69
5 June 72
K = (17/539)^1/3 = .316
R = .87 hr
K = (5.2/1860)^1/2 = .203
R = .63 hr
K = (8/550)^1/3 = .244
R = .71 hr
25410
Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch
10 June 1969

27 July 87

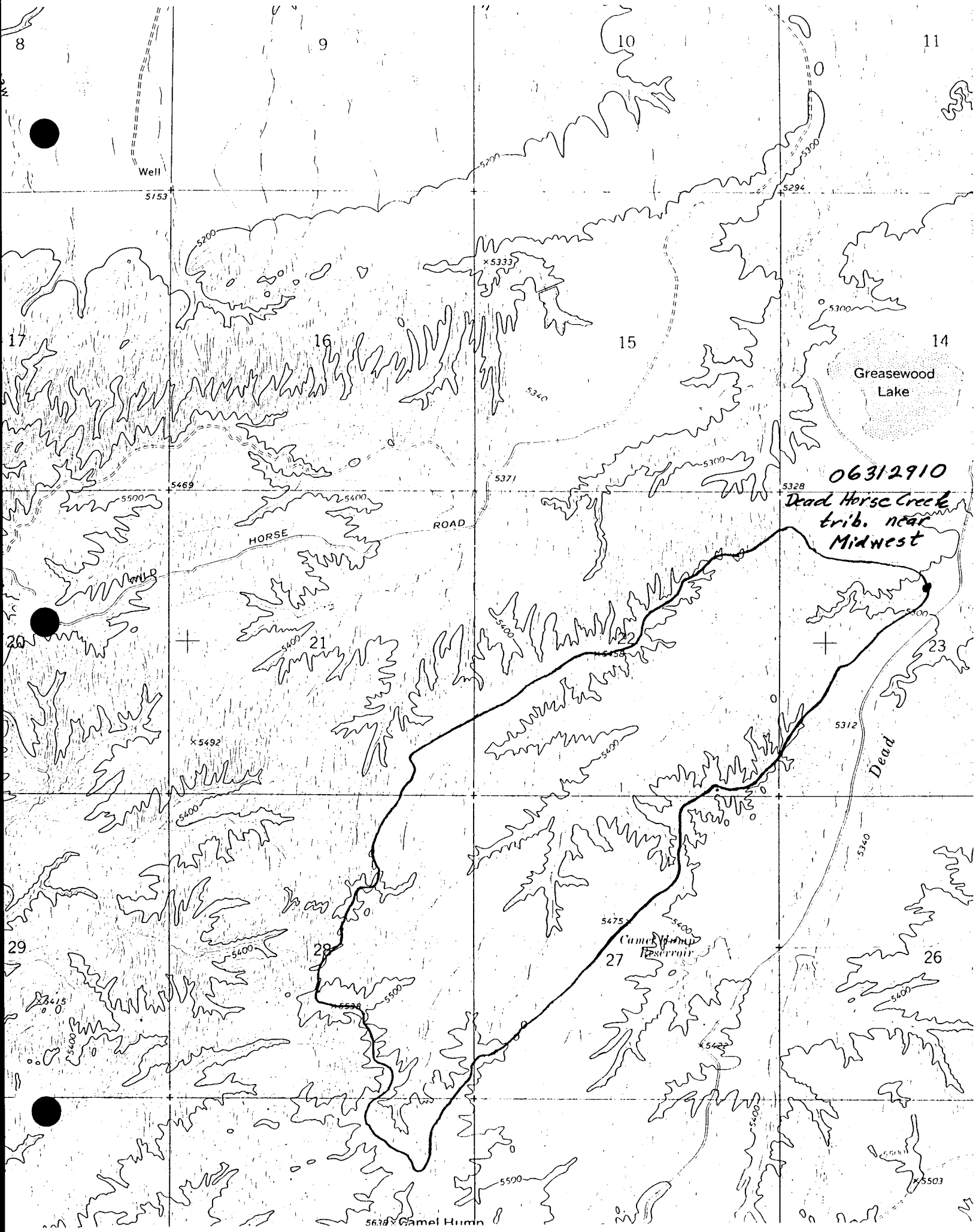
Flood Reconstitution for Wyoming Dead Horse Creek WDH1

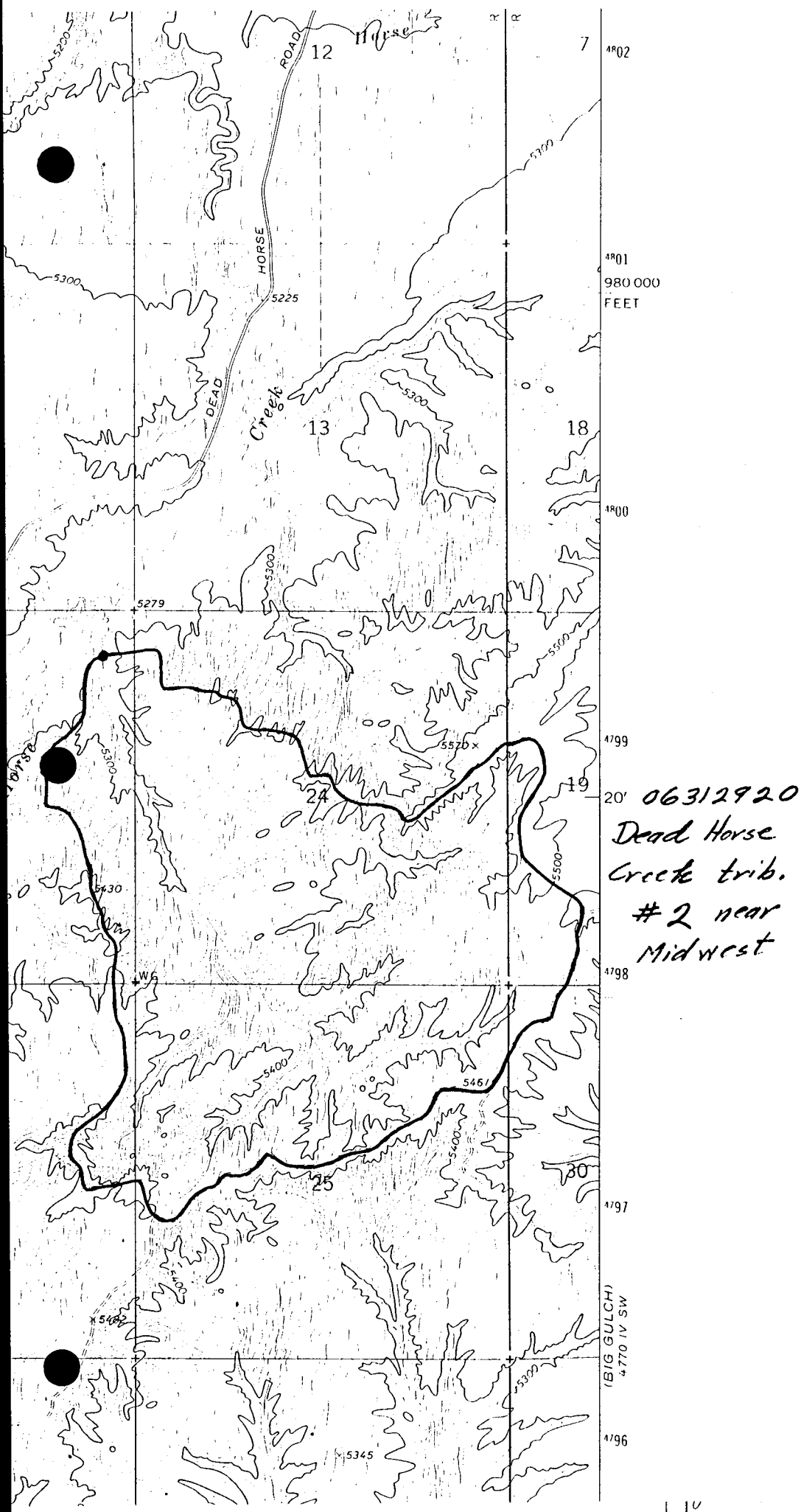
Storm Event 3 June 72

Runoff: depth = 1.12 inches, Q_p = 2040 cfs at t_p = .83 hours

$R_{recession}$ = .44 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
979.2	0	1.22	5	D		1298	.83	.95	.25	.10	.02	Ø01	
"	"	"	"	N-1		1693	.83	.74	.34	.08	.06	Ø02	← best


06312910
Dead Horse Creek trib. near Midwest
Greasewood Lake
HORSE ROAD
Well
Dead
Camel Hump Reservoir
Camel Hump
8
9
10
11
17
16
15
14
20
21
22
23
29
28
27
26
5153
5200
5294
5300
5333
5340
5371
5328
5469
5500
5400
5458
5492
5312
5475
5415
5598
5422
5503
5638



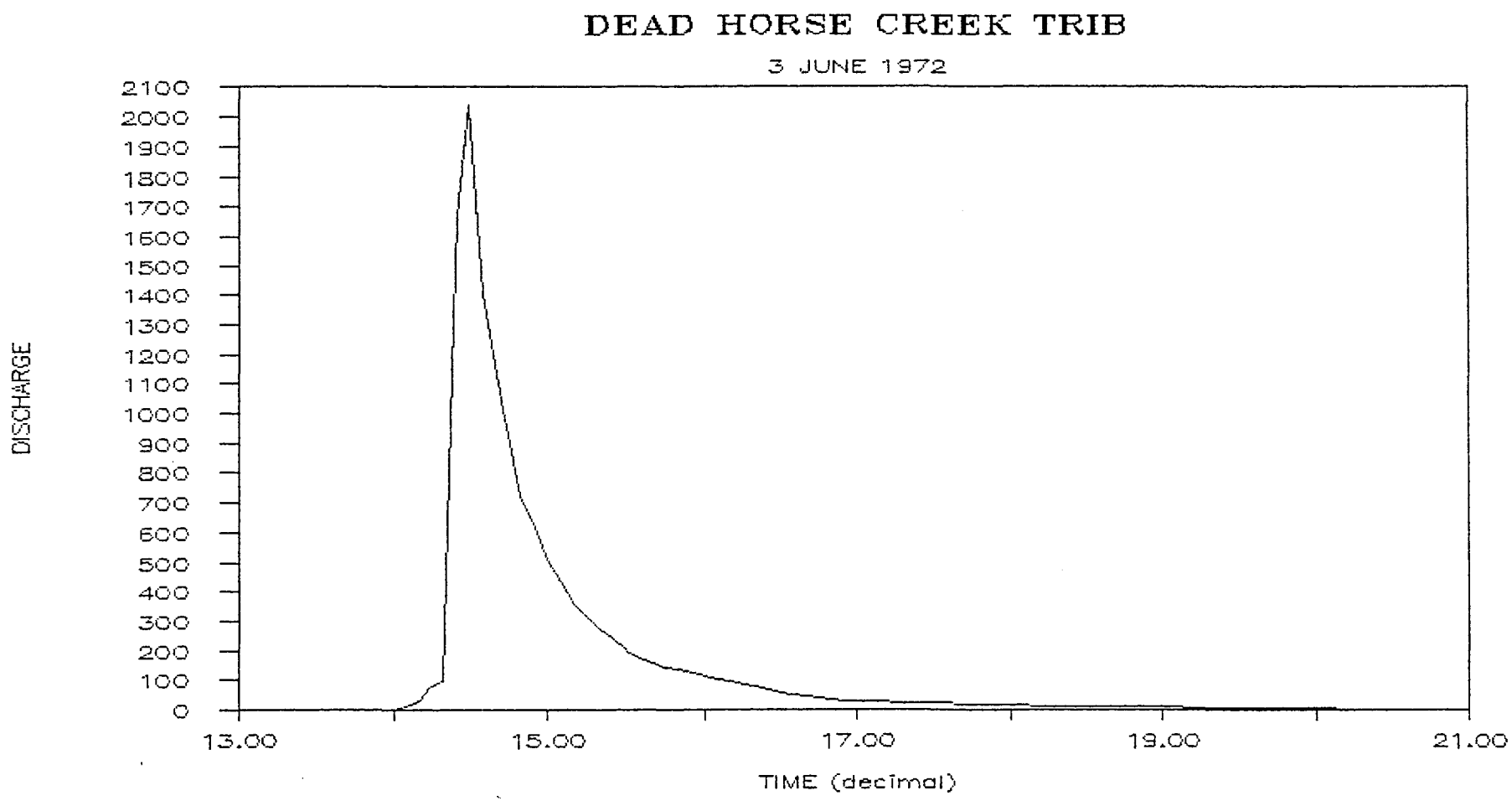
06312920
Dead Horse
Creek trib.
#2 near
Midwest

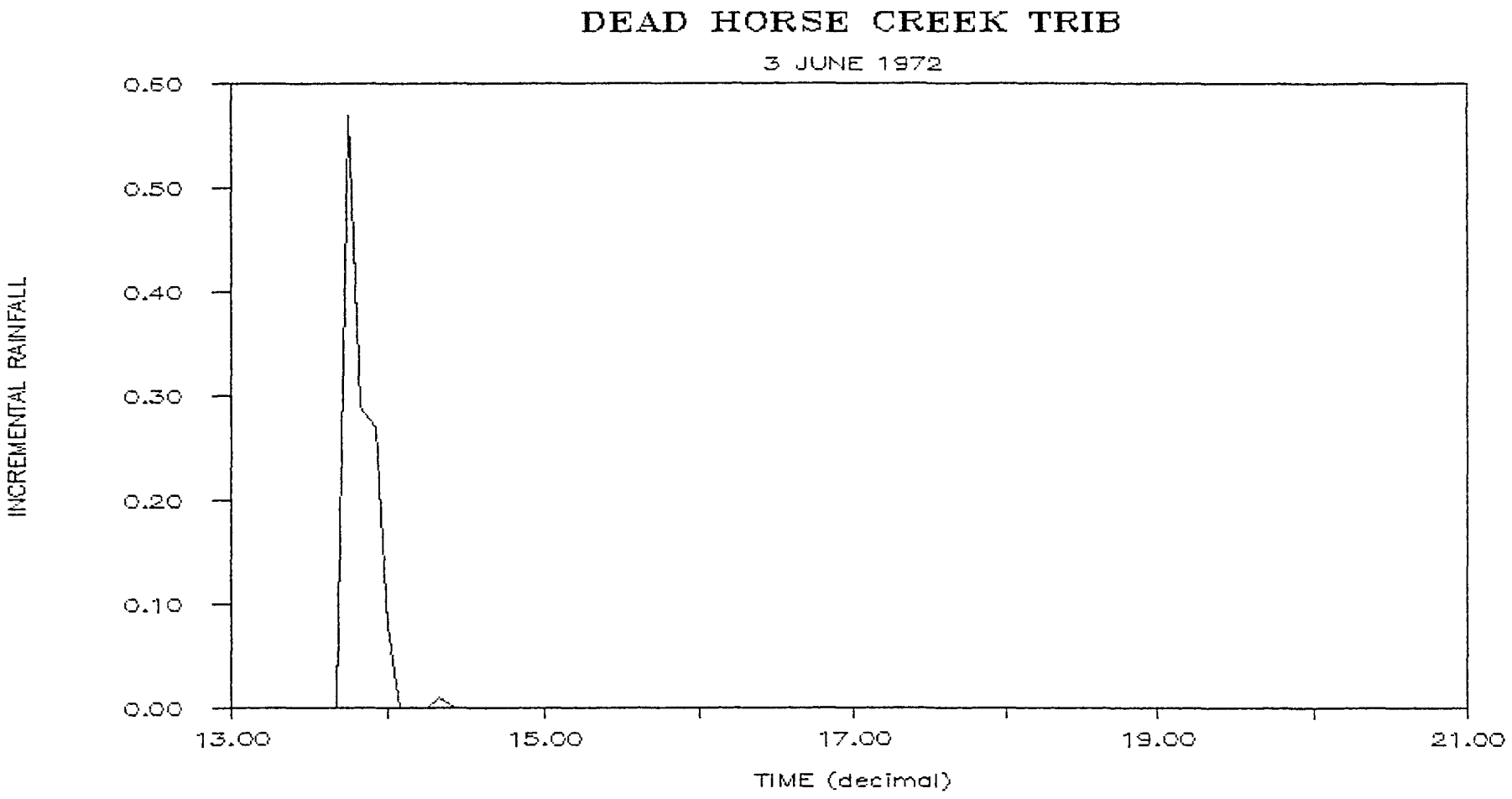
WYOMING DATA
DEAD HORSE CREEK T

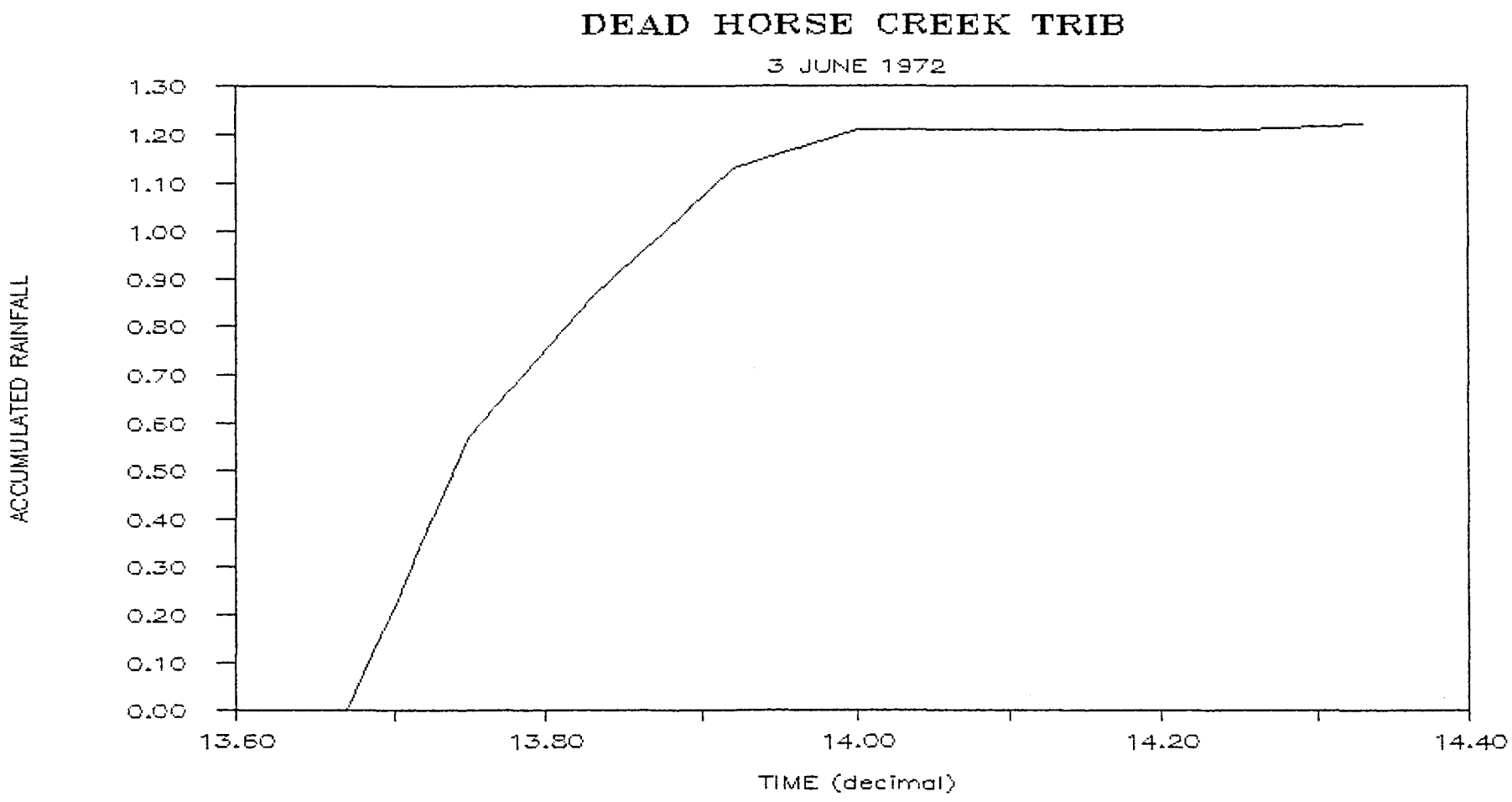
3 5 JUNE 1972

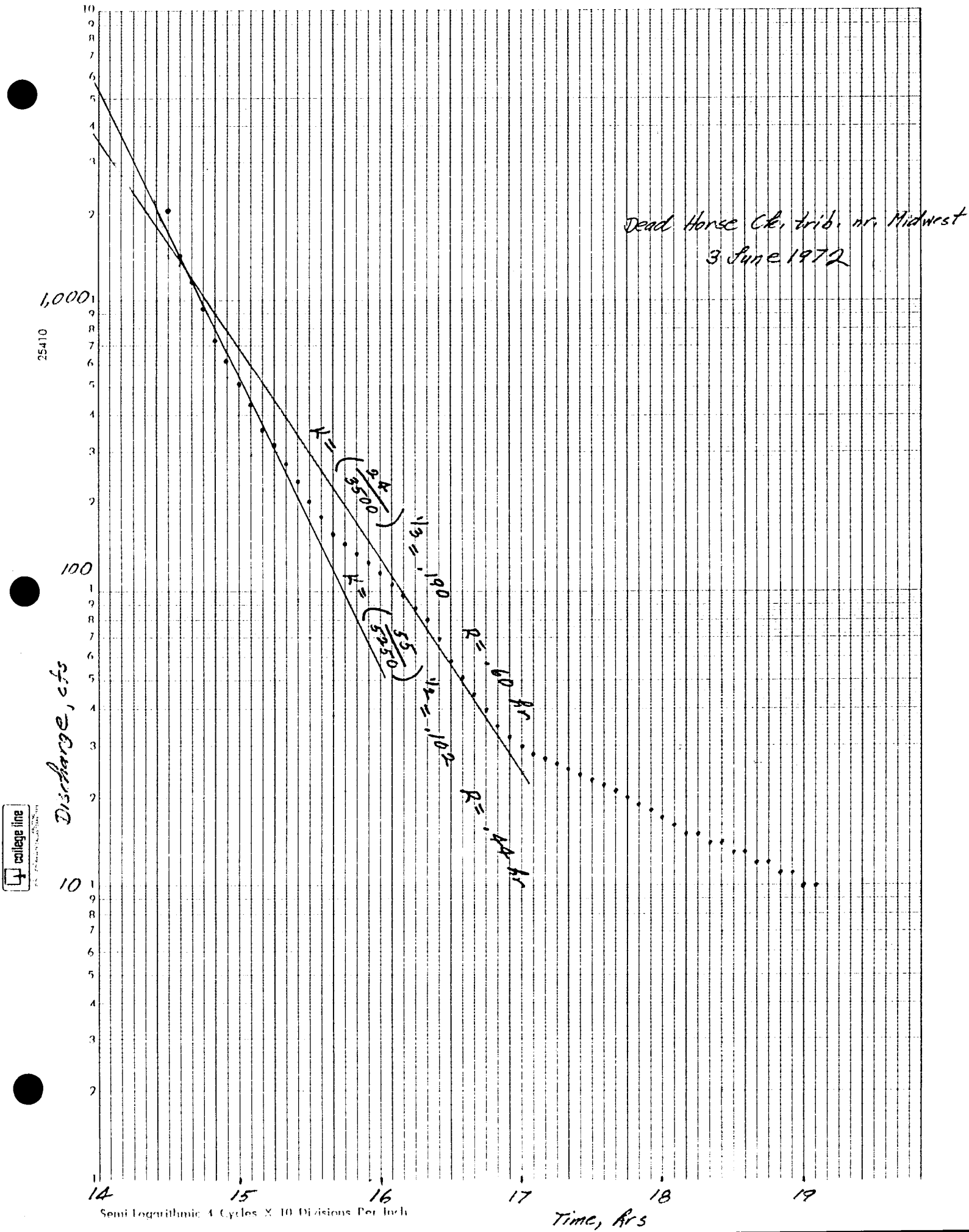
TIME	Q	P1	SUM P1
1340	0.00	0.00	0.00
1345	0.00	0.57	0.57
1350	0.00	0.29	0.86
1355	1.00	0.27	1.13
1400	2.00	0.08	1.21
1405	10.00	0.00	1.21
1410	30.00	0.00	1.21
1415	82.00	0.00	1.21
1420	98.00	0.01	1.22
1425	1670.00	0.00	1.22
1430	2040.00	0.00	1.22
1435	1410.00	0.00	1.22
1440	1130.00	0.00	1.22
1445	927.00	0.00	1.22
1450	724.00	0.00	1.22
1455	618.00	0.00	1.22
1500	511.00	0.00	1.22
1505	434.00	0.00	1.22
1510	357.00	0.00	1.22
1515	315.00	0.00	1.22
1520	273.00	0.00	1.22
1525	237.00	0.00	1.22
1530	201.00	0.00	1.22
1535	179.00	0.00	1.22
1540	157.00	0.00	1.22
1545	145.00	0.00	1.22
1550	134.00	0.00	1.22
1555	124.00	0.00	1.22
1600	114.00	0.00	1.22
1605	105.00	0.00	1.22
1610	97.00	0.00	1.22
1615	88.00	0.00	1.22
1620	80.00	0.00	1.22
1625	69.00	0.00	1.22
1630	58.00	0.00	1.22
1635	51.00	0.00	1.22
1640	45.00	0.00	1.22
1645	40.00	0.00	1.22
1650	35.00	0.00	1.22
1655	32.00	0.00	1.22
1700	30.00	0.00	1.22
1705	28.00	0.00	1.22
1710	27.00	0.00	1.22
1715	26.00	0.00	1.22
1720	25.00	0.00	1.22
1725	24.00	0.00	1.22
1730	23.00	0.00	1.22
1735	22.00	0.00	1.22
1740	21.00	0.00	1.22
1745	20.00	0.00	1.22
1750	19.00	0.00	1.22
1755	18.00	0.00	1.22

1800	17.00	0.00	1.22
1805	16.00	0.00	1.22
1810	15.00	0.00	1.22
1815	15.00	0.00	1.22
1820	14.00	0.00	1.22
1825	14.00	0.00	1.22
1830	13.00	0.00	1.22
1835	13.00	0.00	1.22
1840	12.00	0.00	1.22
1845	12.00	0.00	1.22
1850	11.00	0.00	1.22
1855	11.00	0.00	1.22
1900	10.00	0.00	1.22
1905	10.00	0.00	1.22
1910	9.50	0.00	1.22
1915	9.50	0.00	1.22
1920	9.00	0.00	1.22
1925	8.50	0.00	1.22
1930	8.00	0.00	1.22
1935	7.50	0.00	1.22
1940	7.00	0.00	1.22
1945	6.50	0.00	1.22
1950	6.00	0.00	1.22
1955	5.50	0.00	1.22
2000	5.00	0.00	1.22
2005	4.50	0.00	1.22
2010	4.00	0.00	1.22
2015	3.60	0.00	1.22
2020	3.20	0.00	1.22
2025	2.80	0.00	1.22
2030	2.40	0.00	1.22
2035	2.00	0.00	1.22
2040	1.60	0.00	1.22
2045	1.20	0.00	1.22
2050	0.80	0.00	1.22
2055	0.40	0.00	1.22
2100	0.00	0.00	1.22


DEAD HORSE CREEK TRIB
3 JUNE 1972
DISCHARGE
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
13.00
15.00
17.00
19.00
21.00
TIME (decimal)


DEAD HORSE CREEK TRIB
3 JUNE 1972
INCREMENTAL RAINFALL
0.60
0.50
0.40
0.30
0.20
0.10
0.00
13.00
15.00
17.00
19.00
21.00
TIME (decimal)


DEAD HORSE CREEK TRIB
3 JUNE 1972
ACCUMULATED RAINFALL
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
13.60
13.80
14.00
14.20
14.40
TIME (decimal)


Dead Horse Ck, trib. nr. Midwest
3 June 1972
K = (24/3500)
K = (55/5250)
R = .60 hr
R = .44 hr
Discharge, cfs
Time, hrs
1,000
100
10
14
15
16
17
18
19
25410
Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch

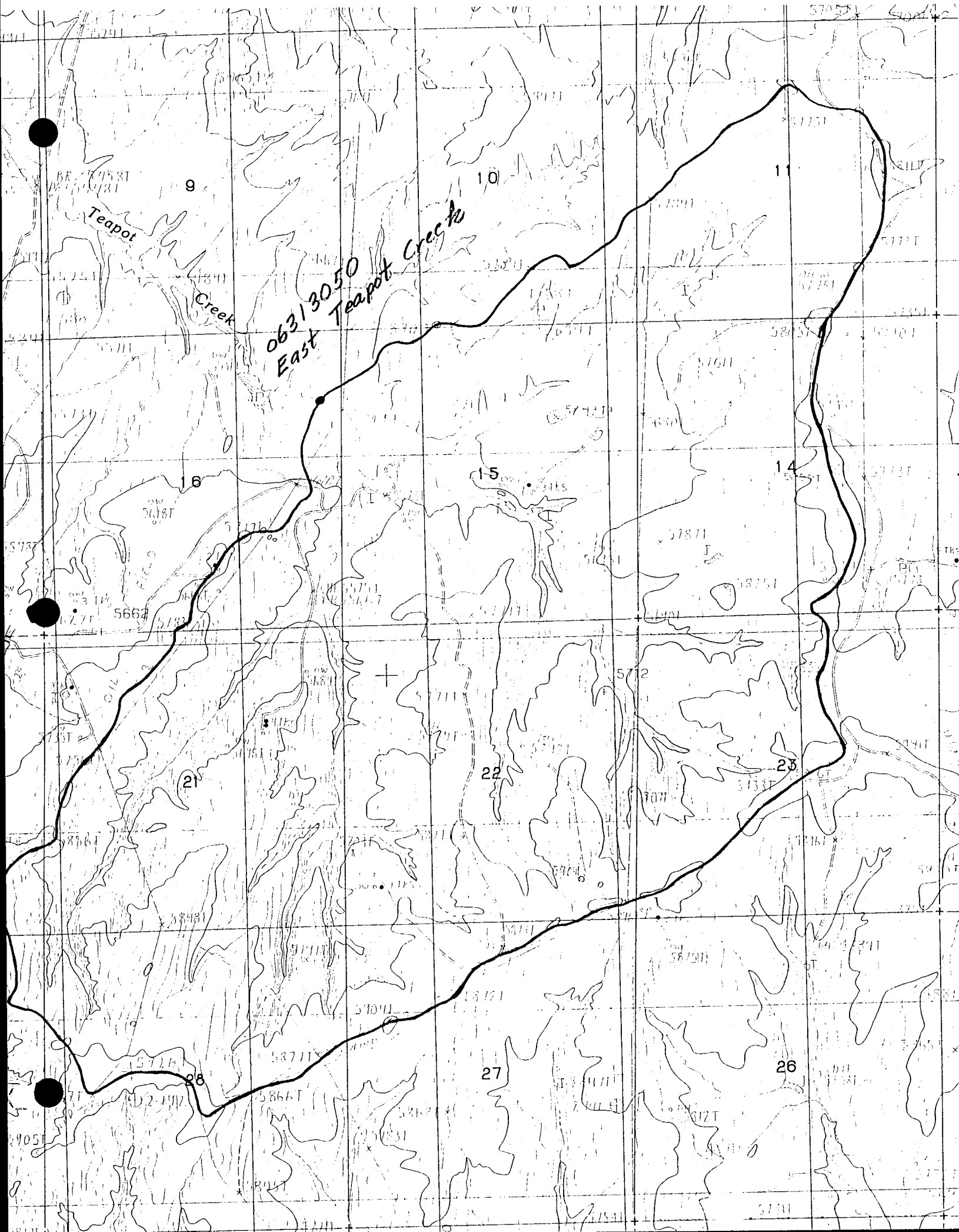
Flood Reconstitution for Wyoming East Trapot Ck WET 1

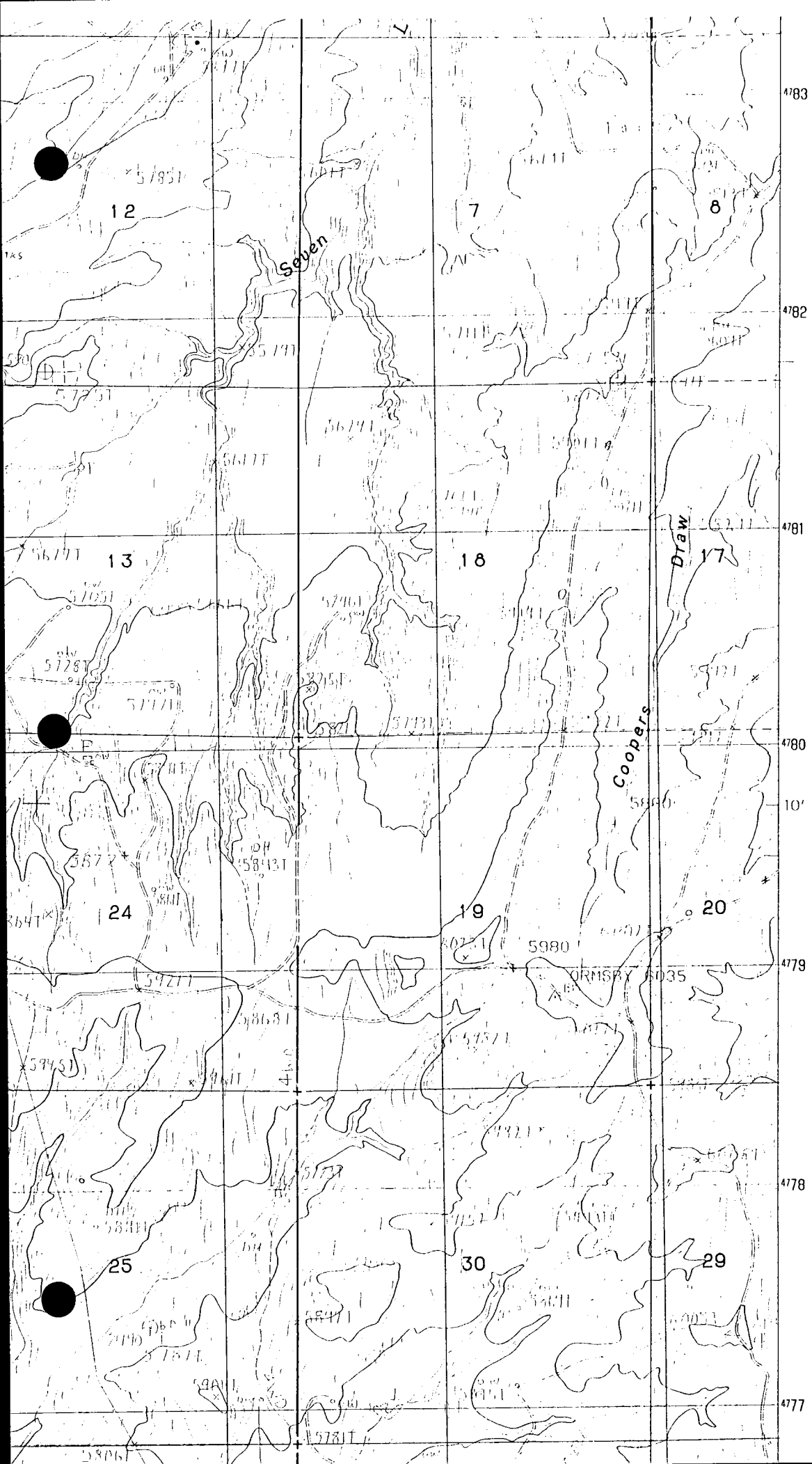
Storm Event 10 June 65

Runoff: depth = .63 inches, Q_p = 4,450 cfs at t_p = 1.58 hours

$R_{recession}$ = .41 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
3482.	0	1.56	5	D		4212	1.58	.35	.11	.92	.05	Ø01	rainfall may not be uniform over watershed
"	"	"	"	N-1		4174	1.50	.24	.14	.89	.11	Ø2	
"	"	"	"	N-2		4625	1.50	.47	.06	.88	.12	Ø3	
"	"	"	"	N-6		4031	1.58	.39	.12	.88	.12	Ø4	← best


06313050
East Teapot Creek
Teapot
Creek
9
10
11
16
15
14
21
22
23
28
27
26
5663
5712

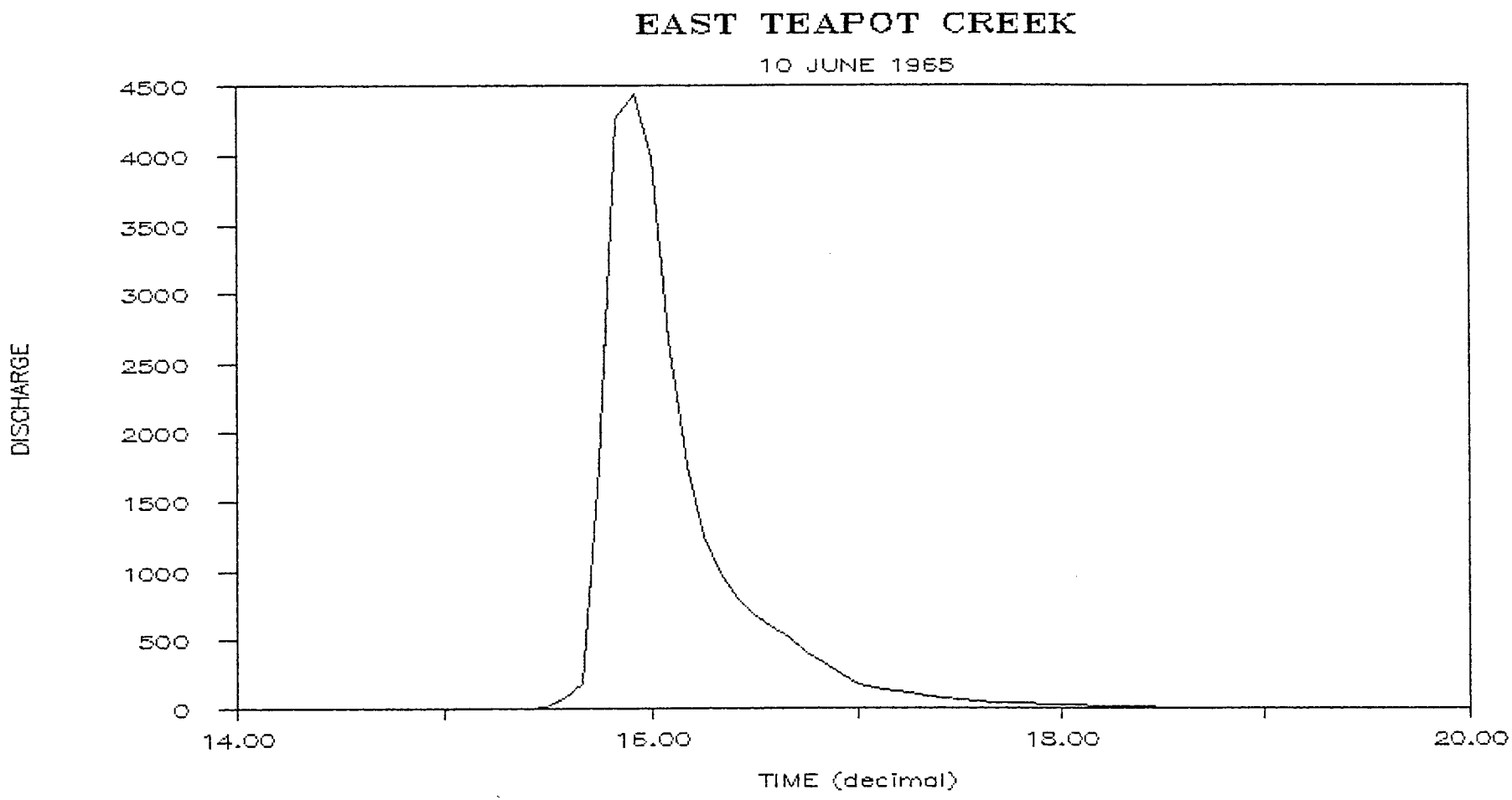

12
7
8
Seven
13
18
17
Draw
Coopers
24
19
20
5980
ORMSBY
25
30
29
4783
4782
4781
4780
10'
4779
4778
4777

WYOMING DATA
EAST TEAPOT CRE

10 JUNE 1965

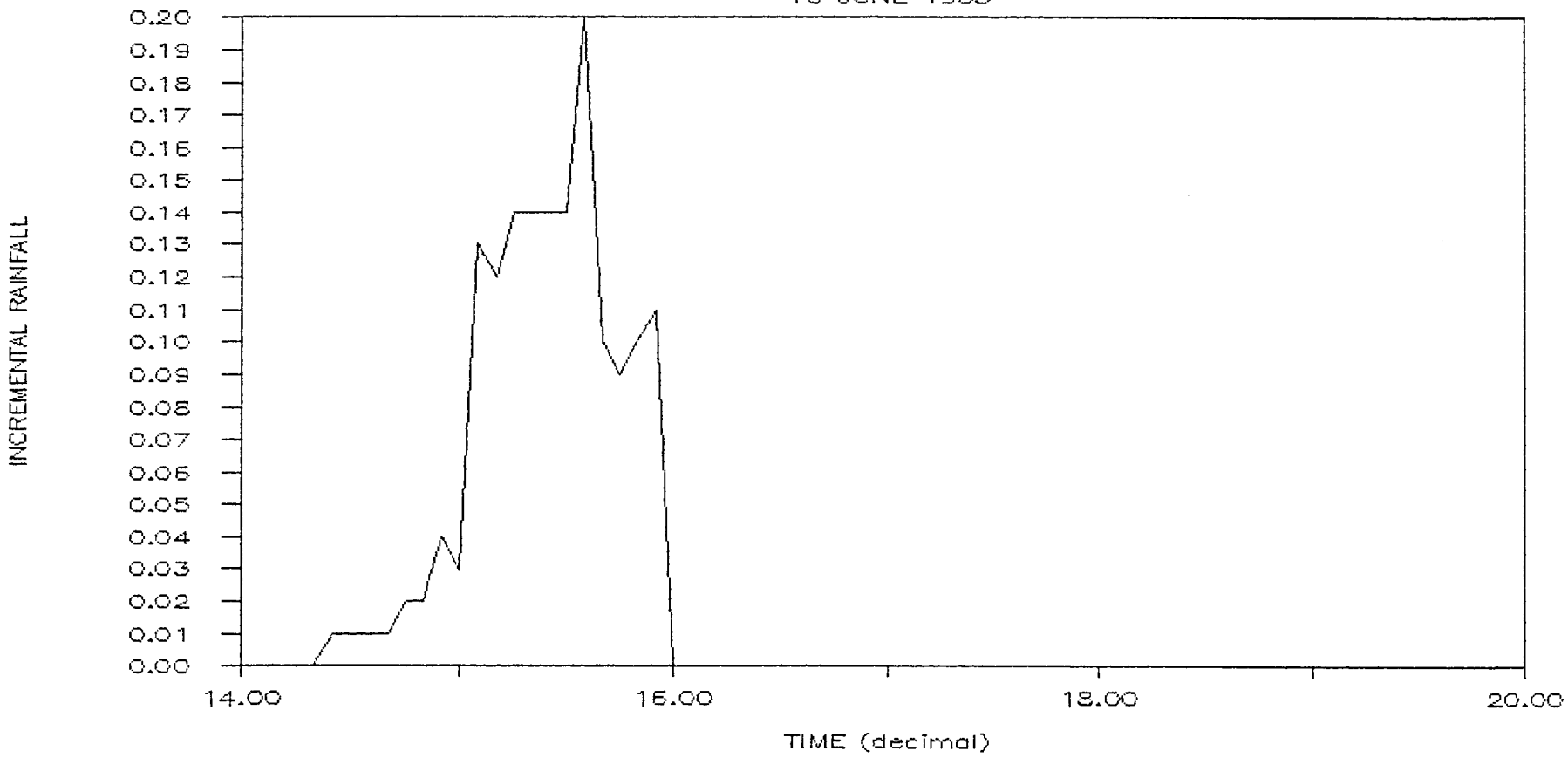
TIME	Q	P1	SUM P1
1420	0.00	0.00	0.00
1425	0.00	0.01	0.01
1430	0.00	0.01	0.02
1435	0.00	0.01	0.03
1440	0.00	0.01	0.04
1445	0.00	0.02	0.06
1450	0.00	0.02	0.08
1455	0.00	0.04	0.12
1500	0.00	0.03	0.15
1505	0.00	0.13	0.28
1510	0.00	0.12	0.40
1515	0.00	0.14	0.54
1520	0.00	0.14	0.68
1525	2.00	0.14	0.82
1530	15.00	0.14	0.96
1535	79.00	0.20	1.16
1540	180.00	0.10	1.26
1545	1760.00	0.09	1.35
1550	4270.00	0.10	1.45
1555	4450.00	0.11	1.56
1600	3990.00	0.00	1.56
1605	2670.00	0.00	1.56
1610	1760.00	0.00	1.56
1615	1250.00	0.00	1.56
1620	978.00	0.00	1.56
1625	800.00	0.00	1.56
1630	679.00	0.00	1.56
1635	595.00	0.00	1.56
1640	517.00	0.00	1.56
1645	406.00	0.00	1.56
1650	327.00	0.00	1.56
1655	241.00	0.00	1.56
1700	178.00	0.00	1.56
1705	150.00	0.00	1.56
1710	123.00	0.00	1.56
1715	106.00	0.00	1.56
1720	90.00	0.00	1.56
1725	77.00	0.00	1.56
1730	64.00	0.00	1.56
1735	54.00	0.00	1.56
1740	45.00	0.00	1.56
1745	40.00	0.00	1.56
1750	34.00	0.00	1.56
1755	29.00	0.00	1.56
1800	24.00	0.00	1.56
1805	21.00	0.00	1.56
1810	18.00	0.00	1.56
1815	15.00	0.00	1.56
1820	12.00	0.00	1.56
1825	10.00	0.00	1.56
1830	8.00	0.00	1.56
1835	6.00	0.00	1.56

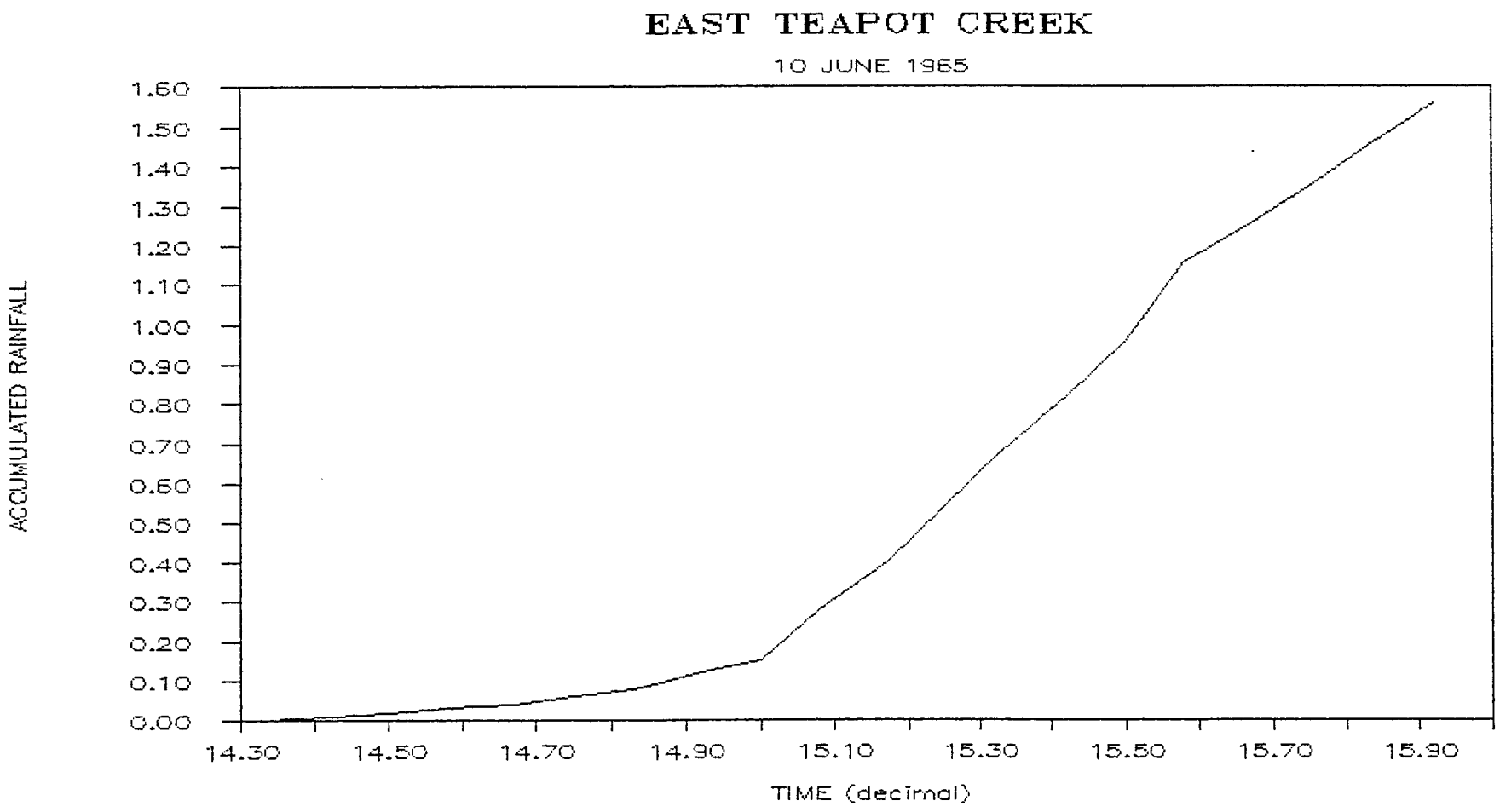
1840	4.00	0.00	1.56
1845	3.00	0.00	1.56
1850	2.00	0.00	1.56
1855	1.00	0.00	1.56
1900	1.00	0.00	1.56
1905	1.00	0.00	1.56
1910	1.00	0.00	1.56
1915	1.00	0.00	1.56
1920	0.00	0.00	1.56

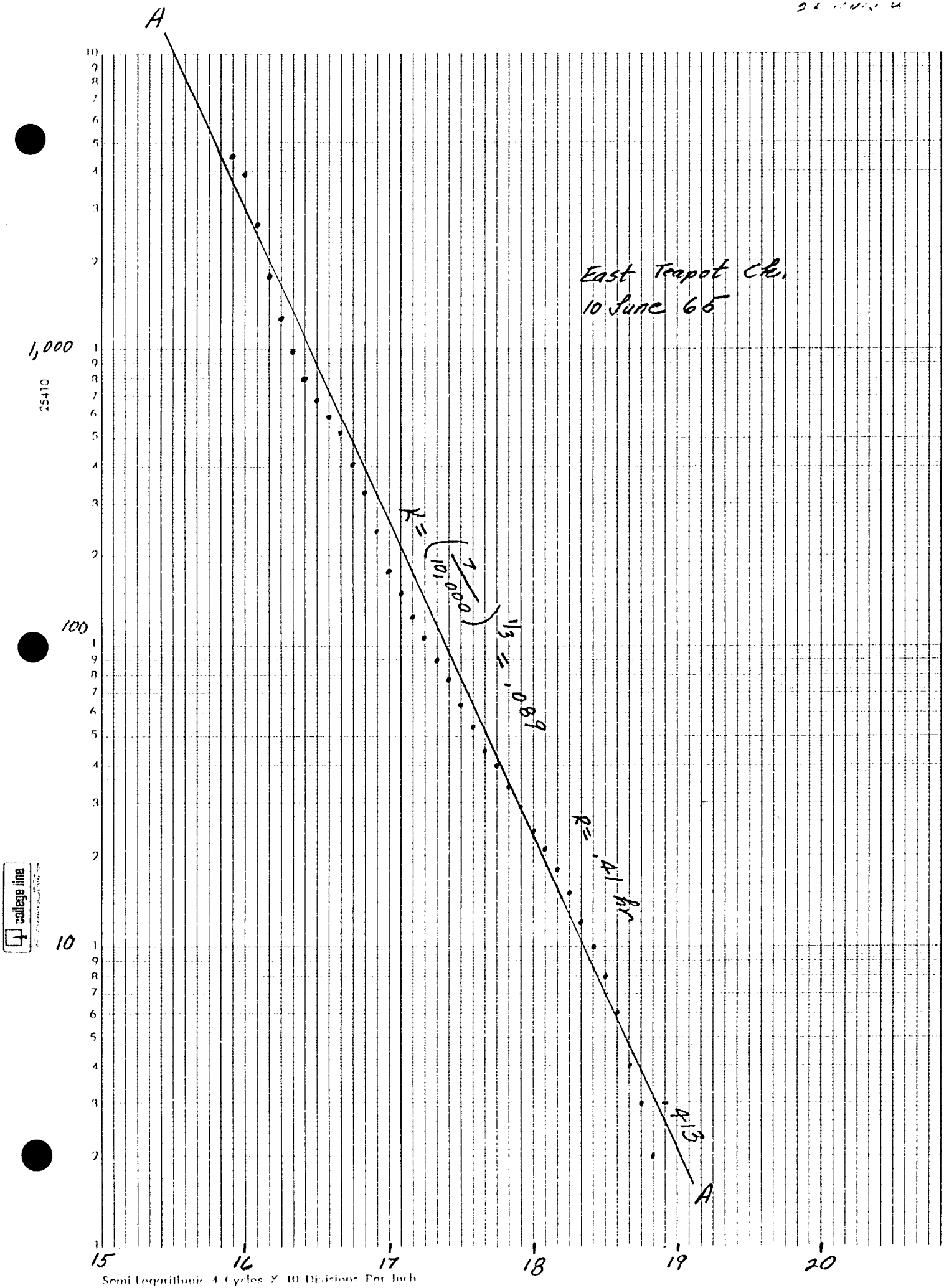

EAST TEAPOT CREEK
10 JUNE 1965
DISCHARGE
4500
4000
3500
3000
2500
2000
1500
1000
500
0
14.00
16.00
18.00
20.00
TIME (decimal)

EAST TEAPOT CREEK

10 JUNE 1965




EAST TEAPOT CREEK
10 JUNE 1965
ACCUMULATED RAINFALL
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
14.30
14.50
14.70
14.90
15.10
15.30
15.50
15.70
15.90
TIME (decimal)


A
East Teapot Cr.
10 June 65
1,000
100
10
25410
K = (1/10,000)^1/3 = .089
R = .41 hr
4 1/3
A
15
16
17
18
19
20
Semi Logarithmic 4 Cycles X 10 Divisions Per Inch

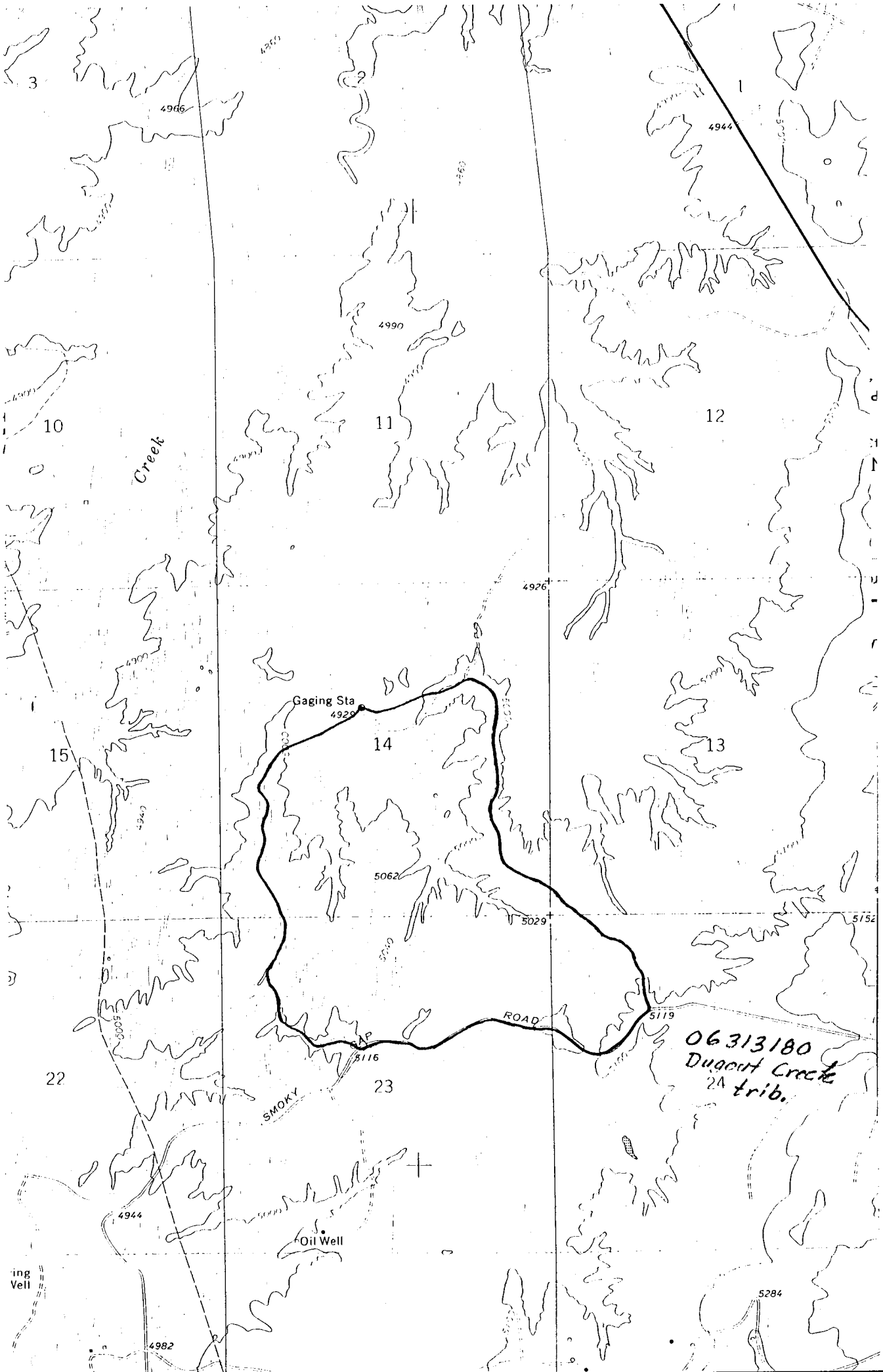
Flood Reconstitution for Wyoming Dugout Ck. WD1

Storm Event 24 June 65

Runoff: depth = .50 inches, Q_p = 493 cfs at t_p = .50 hours

$R_{recession}$ = .16 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
454.4	0	.91	5	D		363	.50	.51	.10	.25	.08	Ø01	
"	"	"	"	Comp.		499	.50	.47	.09	.27	.07	Ø02	← best


3
2
1
4966
4944
4990
10
11
12
Creek
4926
Gaging Sta
4929
14
15
13
5062
5029
5119
ROAD
AP
5116
22
23
24
SMOKY
06313180
Dugout Creek
trib.
4944
Oil Well
5284
4982

DUGOUT CREEK TRIBUTARY
24 JUNE 1965

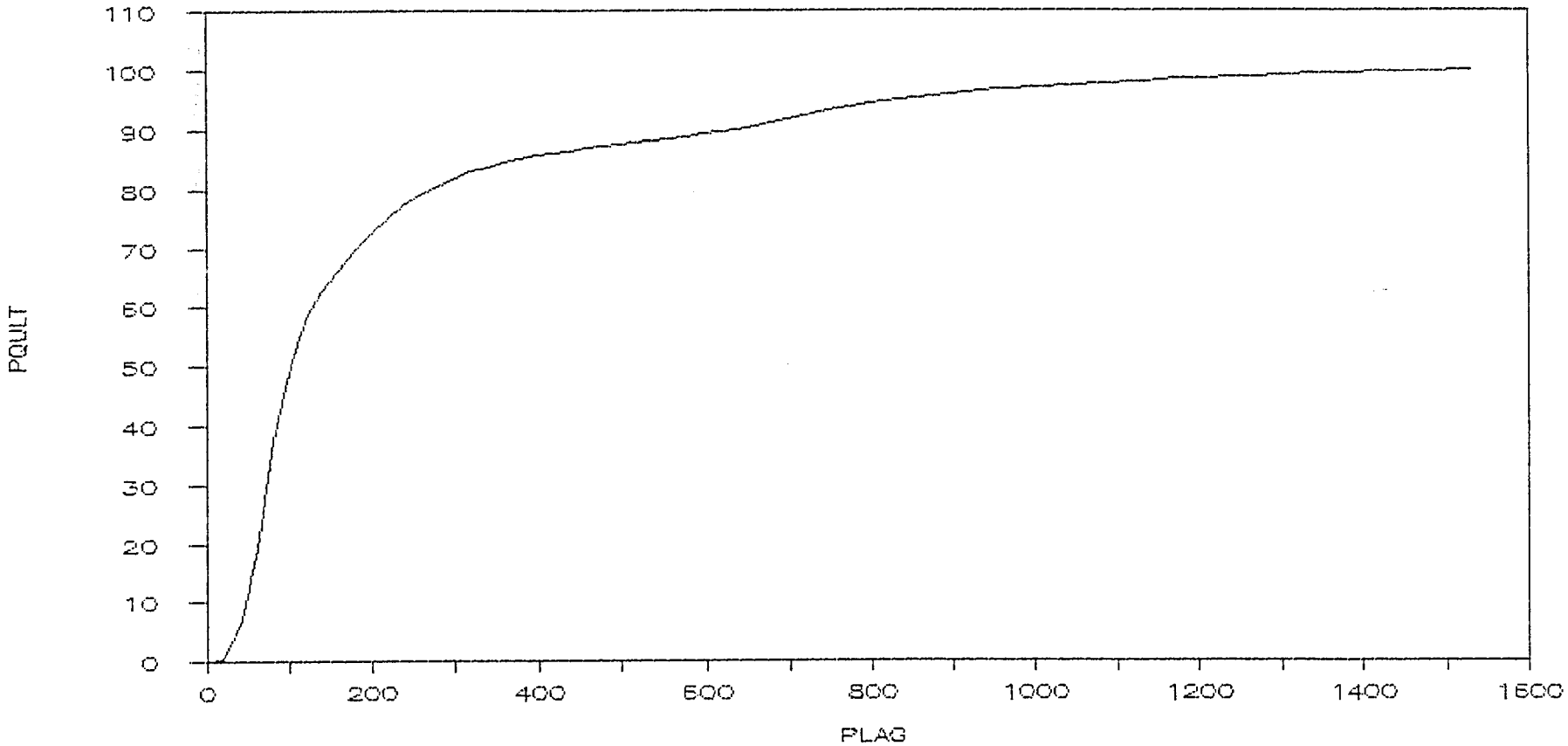
SUM Q	EUD	A	B
2702.00	0.49	2749.13	689.82
LAG	QULT	C	G
0.42	5498.25	0.09	681.69
		q1(F)	q2(E)
		2067.44	2757.26
		t1(H)	t2(X)
		0.33	0.42

TIME	Q	DEC TI	UHG	SUM UHG	PQULT	PLAG
1425	0.00		0.00	0.00		
1430	0.00		0.00	0.00		
1435	0.00	0.00	0.00	0.00	0.00	0.00
1440	7.00	0.08	14.24	14.24	0.26	19.10
1445	183.00	0.17	372.38	386.63	7.03	40.58
1450	333.00	0.25	677.62	1064.24	19.36	59.67
1455	493.00	0.33	1003.20	2067.44	37.60	78.77
1500	339.00	0.42	689.82	2757.26	50.15	100.25
1505	226.00	0.50	459.88	3217.15	58.51	119.35
1510	114.00	0.58	231.98	3449.12	62.73	138.45
1515	99.00	0.67	201.45	3650.58	66.40	159.93
1520	84.00	0.75	170.93	3821.51	69.50	179.02
1525	77.00	0.83	156.69	3978.19	72.35	198.12
1530	70.00	0.92	142.44	4120.64	74.94	219.60
1535	60.00	1.00	122.09	4242.73	77.17	238.70
1540	51.00	1.08	103.78	4346.51	79.05	257.79
1545	43.00	1.17	87.50	4434.01	80.64	279.28
1550	36.00	1.25	73.26	4507.26	81.98	298.37
1555	29.00	1.33	59.01	4566.27	83.05	317.47
1600	23.00	1.42	46.80	4613.08	83.90	338.95
1605	20.00	1.50	40.70	4653.77	84.64	358.05
1610	16.00	1.58	32.56	4686.33	85.23	377.94
1615	14.00	1.67	28.49	4714.82	85.75	397.83
1620	12.00	1.75	24.42	4739.24	86.20	417.72
1625	11.00	1.83	22.38	4761.62	86.60	437.61
1630	10.00	1.92	20.35	4781.97	86.97	457.51
1635	10.00	2.00	20.35	4802.32	87.34	477.40
1640	9.00	2.08	18.31	4820.63	87.68	497.29
1645	9.00	2.17	18.31	4838.95	88.01	517.18
1650	8.00	2.25	16.28	4855.23	88.30	537.07
1655	9.00	2.33	18.31	4873.54	88.64	556.96
1700	9.00	2.42	18.31	4891.86	88.97	576.85
1705	10.00	2.50	20.35	4912.20	89.34	596.75
1710	11.00	2.58	22.38	4934.59	89.75	616.64
1715	12.00	2.67	24.42	4959.01	90.19	636.53
1720	14.00	2.75	28.49	4987.49	90.71	656.42
1725	15.00	2.83	30.52	5018.02	91.27	676.31
1730	16.00	2.92	32.56	5050.58	91.86	696.20
1735	16.00	3.00	32.56	5083.13	92.45	716.10
1740	15.00	3.08	30.52	5113.66	93.01	735.99
1745	14.00	3.17	28.49	5142.15	93.52	755.88
1750	13.00	3.25	26.45	5168.60	94.00	775.77
1755	12.00	3.33	24.42	5193.02	94.45	795.66
1800	10.00	3.42	20.35	5213.37	94.82	815.55
1805	9.00	3.50	18.31	5231.68	95.15	835.44
1810	8.00	3.58	16.28	5247.96	95.45	855.34
1815	8.00	3.67	16.28	5264.24	95.74	875.23
1820	7.00	3.75	14.24	5278.48	96.00	895.12
1825	7.00	3.83	14.24	5292.73	96.26	915.01

1830	6.00	3.92	12.21	5304.94	96.48	934.90
1835	6.00	4.00	12.21	5317.15	96.71	954.79
1840	5.00	4.08	10.17	5327.32	96.89	974.69
1845	5.00	4.17	10.17	5337.49	97.08	994.58
1850	5.00	4.25	10.17	5347.67	97.26	1014.47
1855	4.00	4.33	8.14	5355.81	97.41	1034.36
1900	4.00	4.42	8.14	5363.95	97.56	1054.25
1905	4.00	4.50	8.14	5372.09	97.71	1074.14
1910	4.00	4.58	8.14	5380.23	97.85	1094.03
1915	4.00	4.67	8.14	5388.37	98.00	1113.93
1920	4.00	4.75	8.14	5396.51	98.15	1133.82
1925	4.00	4.83	8.14	5404.65	98.30	1153.71
1930	4.00	4.92	8.14	5412.78	98.45	1173.60
1935	3.00	5.00	6.10	5418.89	98.56	1193.49
1940	3.00	5.08	6.10	5424.99	98.67	1213.38
1945	3.00	5.17	6.10	5431.10	98.78	1233.28
1950	3.00	5.25	6.10	5437.20	98.89	1253.17
1955	3.00	5.33	6.10	5443.31	99.00	1273.06
2000	3.00	5.42	6.10	5449.41	99.11	1292.95
2005	3.00	5.50	6.10	5455.52	99.22	1312.84
2010	3.00	5.58	6.10	5461.62	99.33	1332.73
2015	3.00	5.67	6.10	5467.73	99.44	1352.62
2020	3.00	5.75	6.10	5473.83	99.56	1372.52
2025	2.00	5.83	4.07	5477.90	99.63	1392.41
2030	2.00	5.92	4.07	5481.97	99.70	1412.30
2035	2.00	6.00	4.07	5486.04	99.78	1432.19
2040	2.00	6.08	4.07	5490.11	99.85	1452.08
2045	1.00	6.17	2.03	5492.15	99.89	1471.97
2050	1.00	6.25	2.03	5494.18	99.93	1491.87
2055	1.00	6.33	2.03	5496.21	99.96	1511.76
2100	1.00	6.42	2.03	5498.25	100.00	1531.65

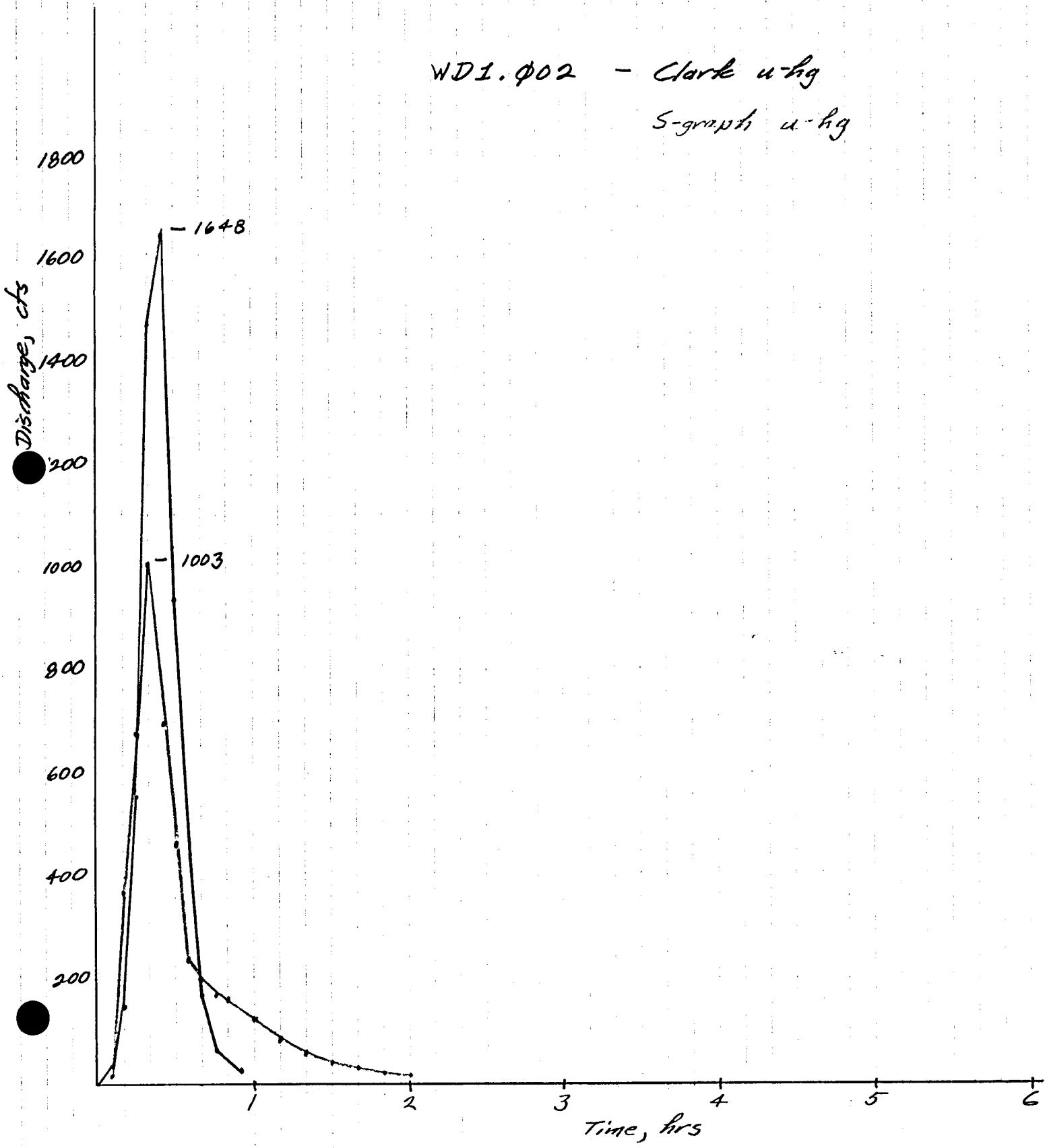
DUGOUT CREEK TRIBUTARY

24 JUNE 1965



10 Sept. 87

Comparison of Unit-hydrographs

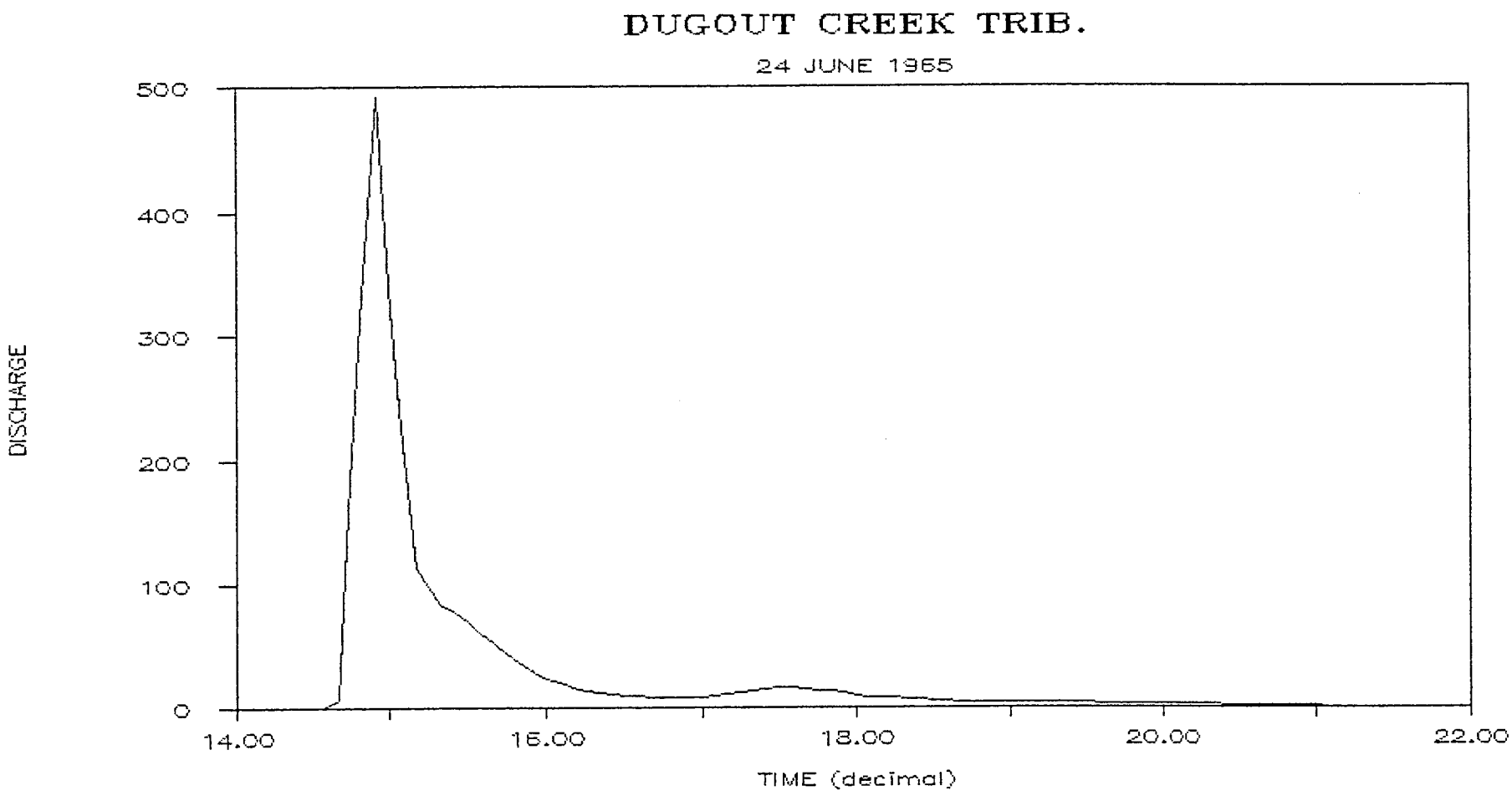


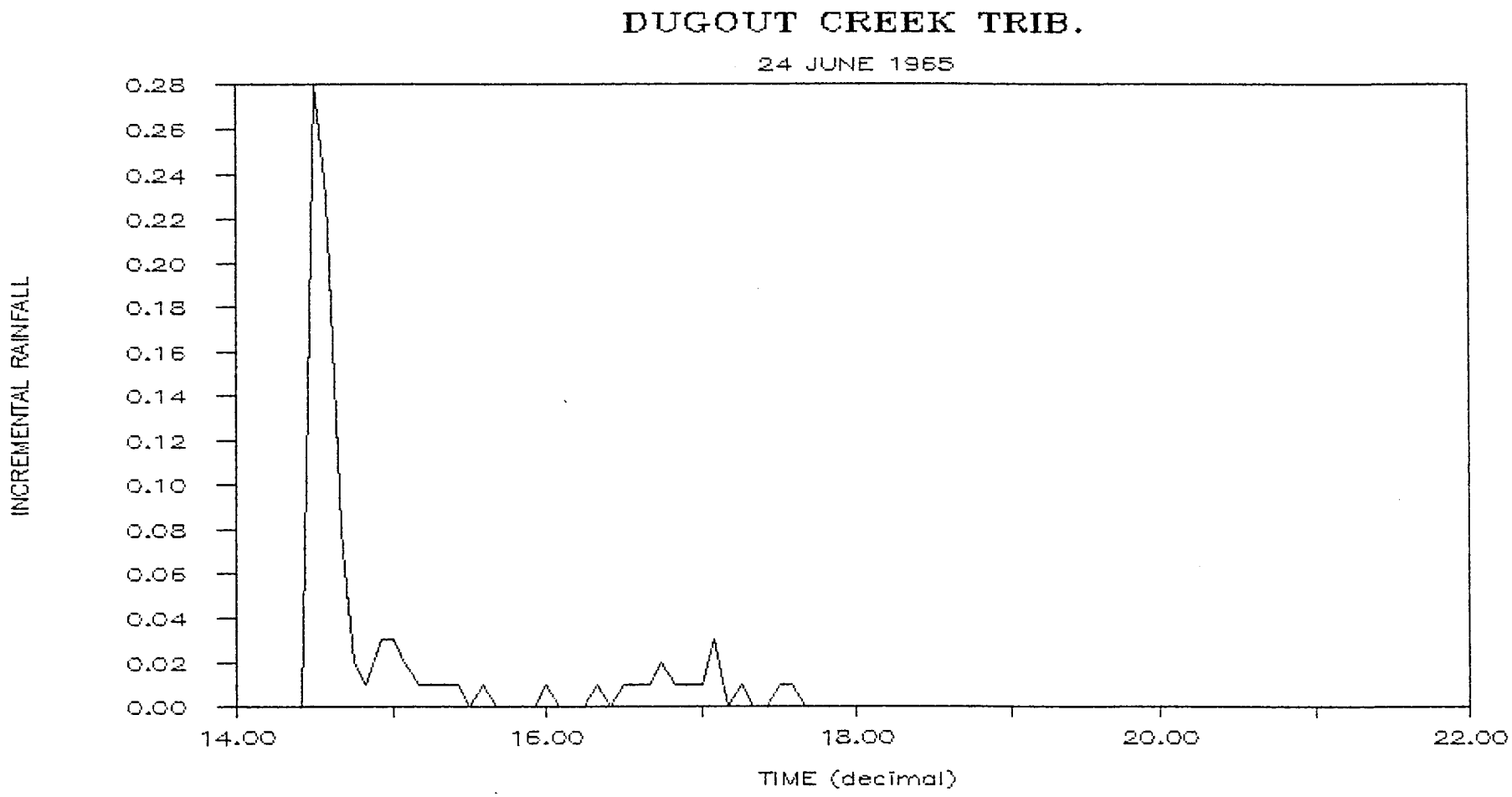
WYOMING DATA
DUGOUT CREEK TRI

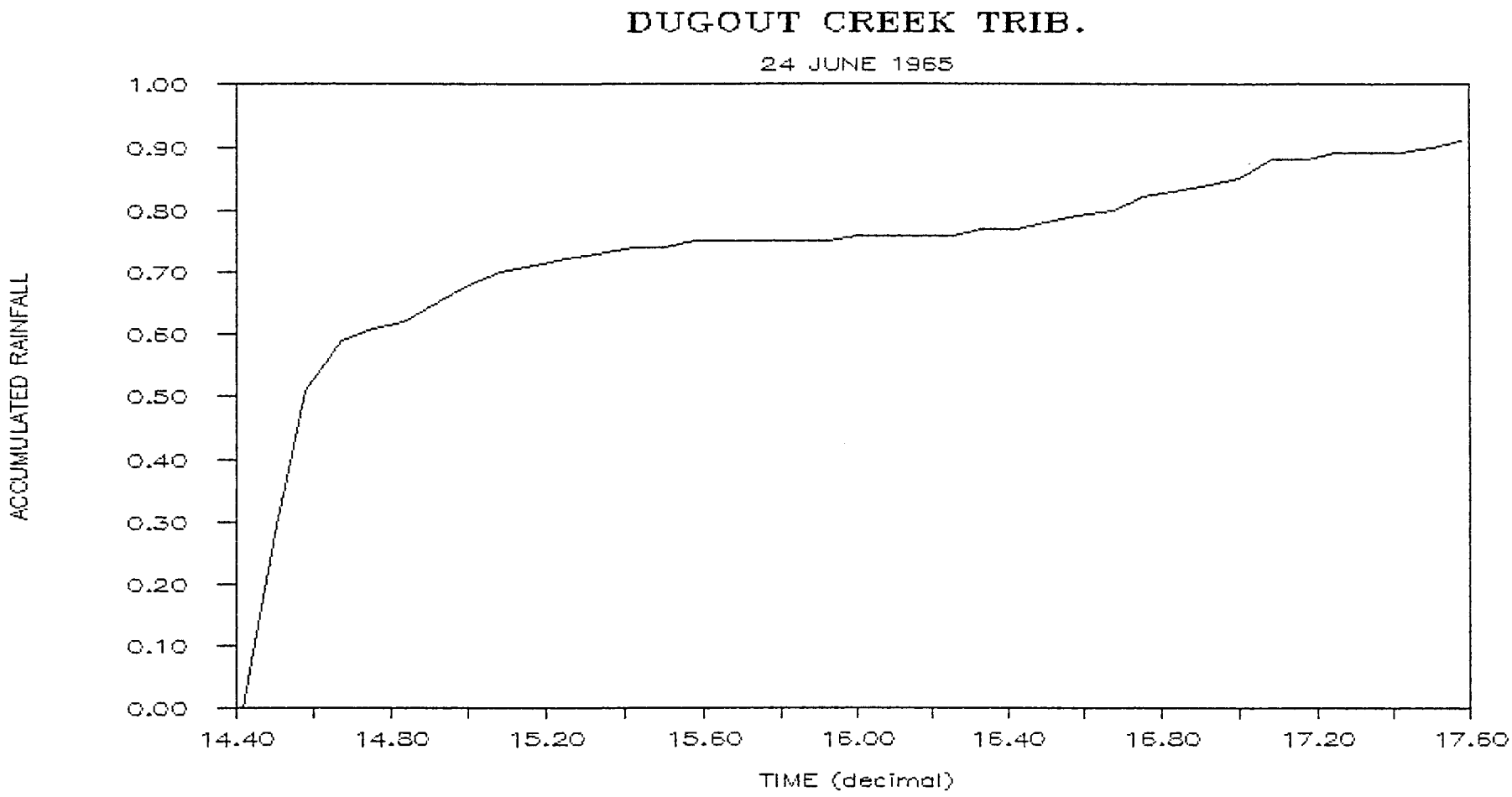
24 JUNE 1965

TIME	Q	P1	SUM P1
1425	0.00	0.00	0.00
1430	0.00	0.28	0.28
1435	0.00	0.23	0.51
1440	7.00	0.08	0.59
1445	183.00	0.02	0.61
1450	333.00	0.01	0.62
1455	493.00	0.03	0.65
1500	339.00	0.03	0.68
1505	226.00	0.02	0.70
1510	114.00	0.01	0.71
1515	99.00	0.01	0.72
1520	84.00	0.01	0.73
1525	77.00	0.01	0.74
1530	70.00	0.00	0.74
1535	60.00	0.01	0.75
1540	51.00	0.00	0.75
1545	43.00	0.00	0.75
1550	36.00	0.00	0.75
1555	29.00	0.00	0.75
1600	23.00	0.01	0.76
1605	20.00	0.00	0.76
1610	16.00	0.00	0.76
1615	14.00	0.00	0.76
1620	12.00	0.01	0.77
1625	11.00	0.00	0.77
1630	10.00	0.01	0.78
1635	10.00	0.01	0.79
1640	9.00	0.01	0.80
1645	9.00	0.02	0.82
1650	8.00	0.01	0.83
1655	9.00	0.01	0.84
1700	9.00	0.01	0.85
1705	10.00	0.03	0.88
1710	11.00	0.00	0.88
1715	12.00	0.01	0.89
1720	14.00	0.00	0.89
1725	15.00	0.00	0.89
1730	16.00	0.01	0.90
1735	16.00	0.01	0.91
1740	15.00	0.00	0.91
1745	14.00	0.00	0.91
1750	13.00	0.00	0.91
1755	12.00	0.00	0.91
1800	10.00	0.00	0.91
1805	9.00	0.00	0.91
1810	8.00	0.00	0.91
1815	8.00	0.00	0.91
1820	7.00	0.00	0.91
1825	7.00	0.00	0.91
1830	6.00	0.00	0.91
1835	6.00	0.00	0.91
1840	5.00	0.00	0.91

1845	5.00	0.00	0.91
1850	5.00	0.00	0.91
1855	4.00	0.00	0.91
1900	4.00	0.00	0.91
1905	4.00	0.00	0.91
1910	4.00	0.00	0.91
1915	4.00	0.00	0.91
1920	4.00	0.00	0.91
1925	4.00	0.00	0.91
1930	4.00	0.00	0.91
1935	3.00	0.00	0.91
1940	3.00	0.00	0.91
1945	3.00	0.00	0.91
1950	3.00	0.00	0.91
1955	3.00	0.00	0.91
2000	3.00	0.00	0.91
2005	3.00	0.00	0.91
2010	3.00	0.00	0.91
2015	3.00	0.00	0.91
2020	3.00	0.00	0.91
2025	2.00	0.00	0.91
2030	2.00	0.00	0.91
2035	2.00	0.00	0.91
2040	2.00	0.00	0.91
2045	1.00	0.00	0.91
2050	1.00	0.00	0.91
2055	1.00	0.00	0.91
2100	1.00	0.00	0.91
2105	0.00	0.00	0.91


DUGOUT CREEK TRIB.
24 JUNE 1965
DISCHARGE
500
400
300
200
100
0
14.00
16.00
18.00
20.00
22.00
TIME (decimal)

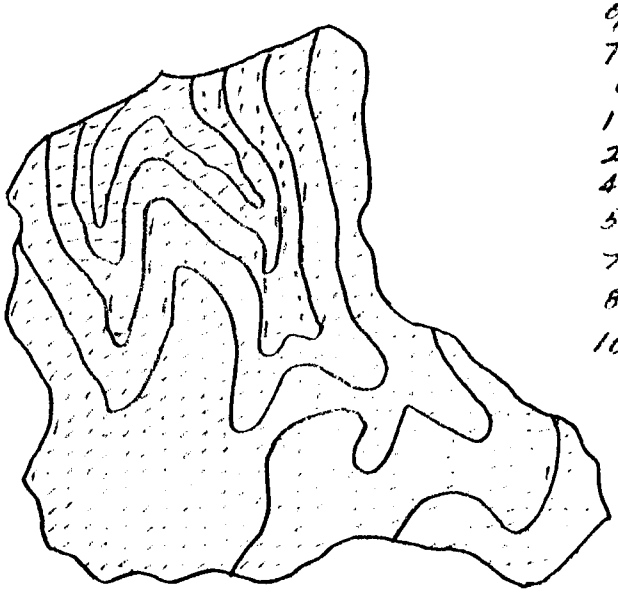

DUGOUT CREEK TRIB.
24 JUNE 1965
INCREMENTAL RAINFALL
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
14.00
16.00
18.00
20.00
22.00
TIME (decimal)


DUGOUT CREEK TRIB.
24 JUNE 1965
ACCUMULATED RAINFALL
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
14.40
14.80
15.20
15.60
16.00
16.40
16.80
17.20
17.60
TIME (decimal)

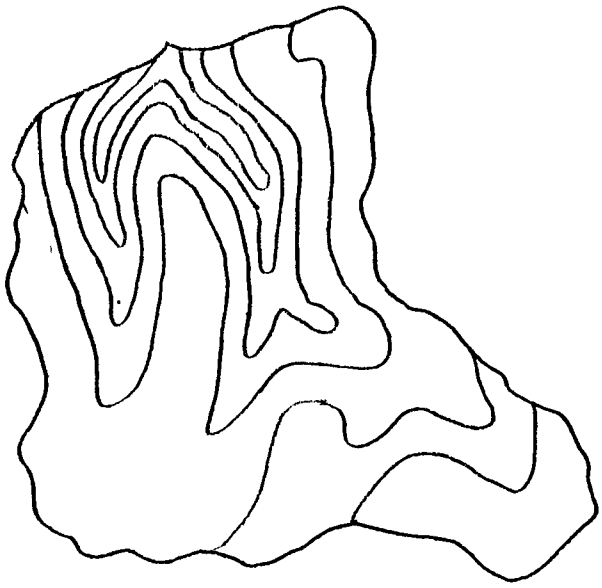
WD 8 Sept 87

elev. of gage – 4,929.
elev. of conc. pt. – 5,119.
} 190 ft

length of channel – 7,980 ft
avg. channel slope – .0238 ft/ft

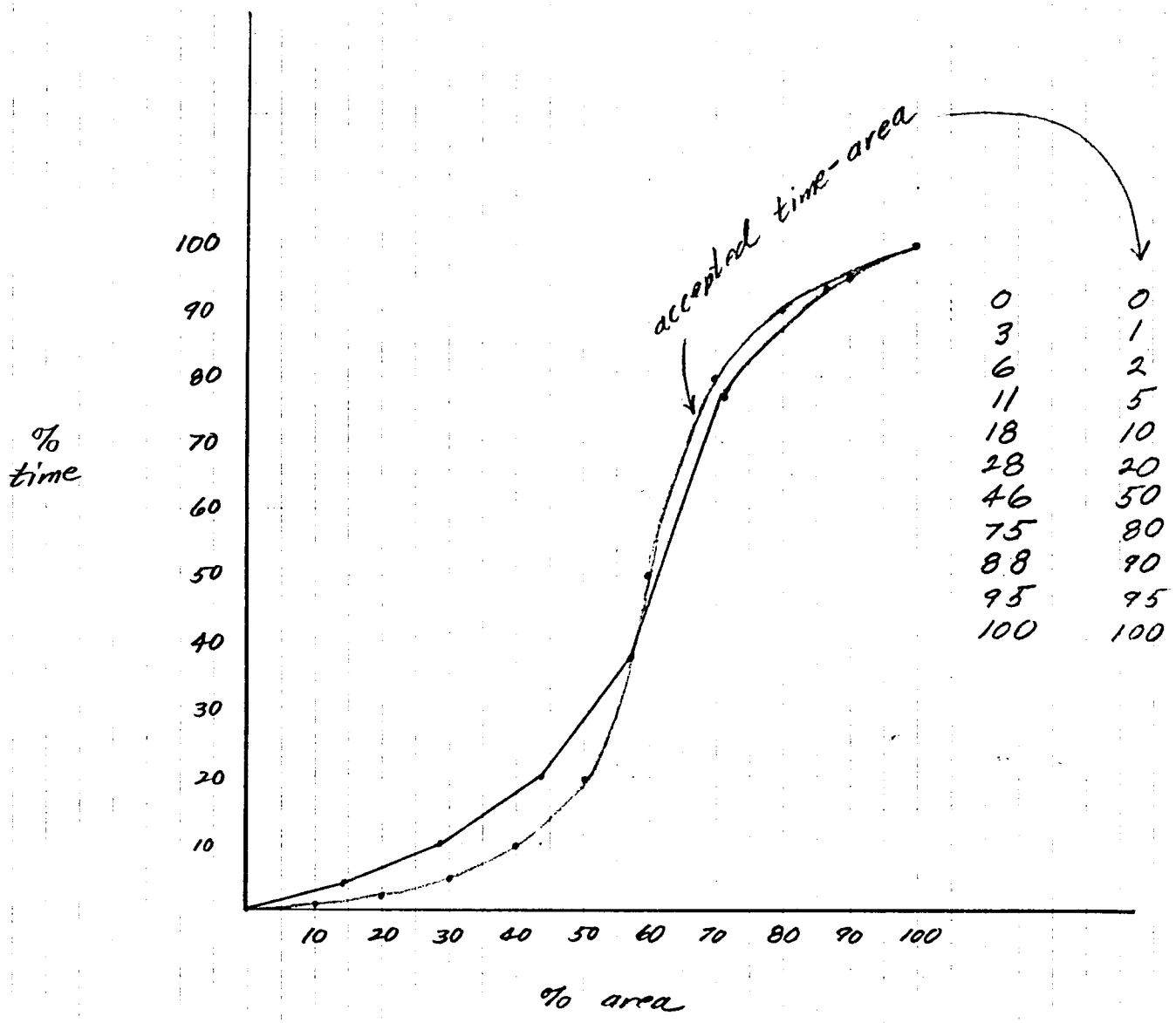


% Time			
0			
14	18	18	4
28	30	48	10
43	52	100	20
57	88	188	38
71	193	381	77
86	83	464	93
100	33	497	100

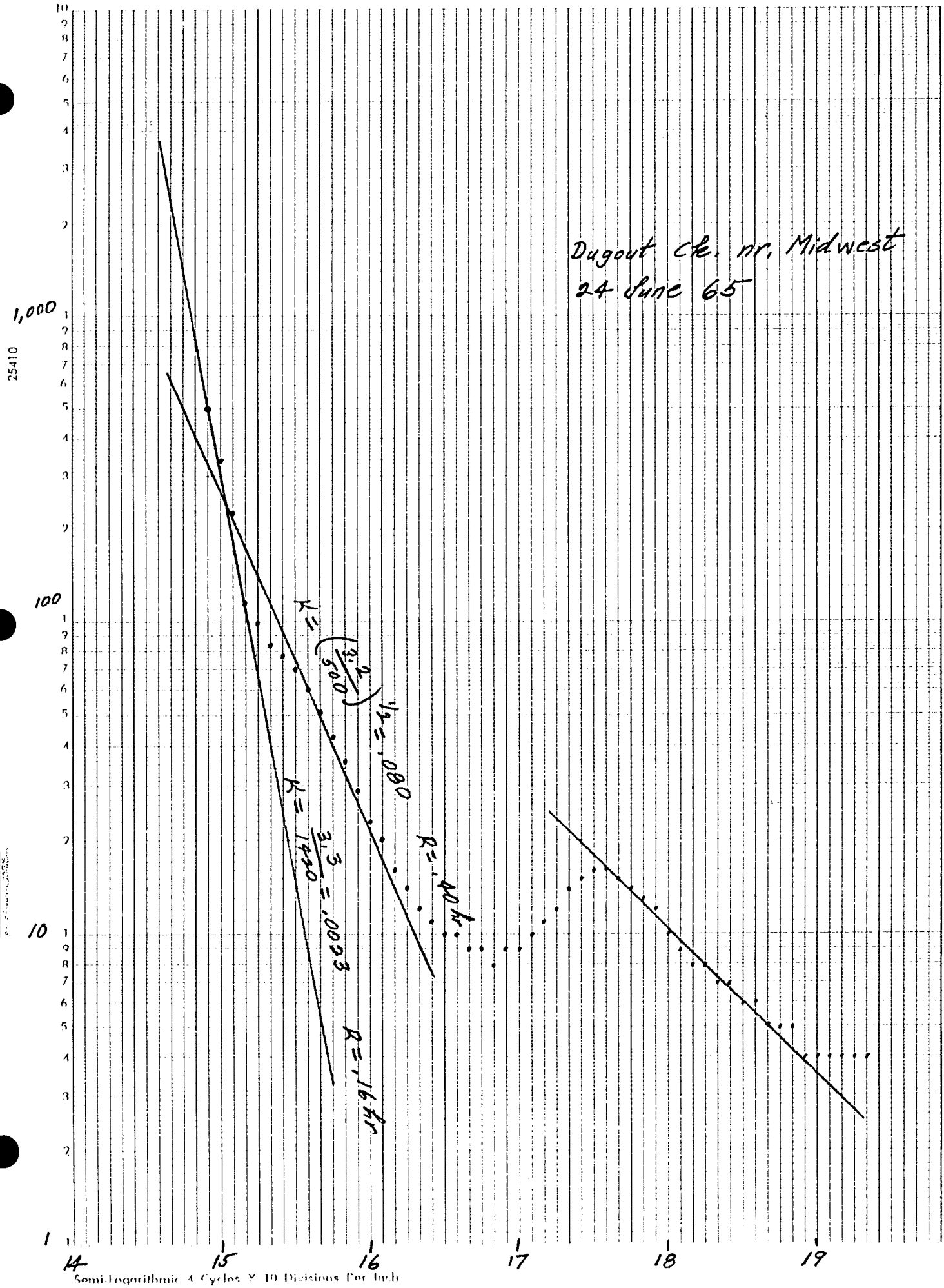


WD

8 Sept 87


accepted time-area
% time
100
90
80
70
60
50
40
30
20
10
10 20 30 40 50 60 70 80 90 100
% area
0 0
3 1
6 2
11 5
18 10
28 20
46 50
75 80
88 90
95 95
100 100

23 July 81


Dugout Cr. nr. Midwest
24 June 65
K = (3.2/500)^1/2 = .080
R = .40 hr.
K = 3.3/1420 = .0023
R = .16 hr
1,000
100
10
1
14
15
16
17
18
19
25410
Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch

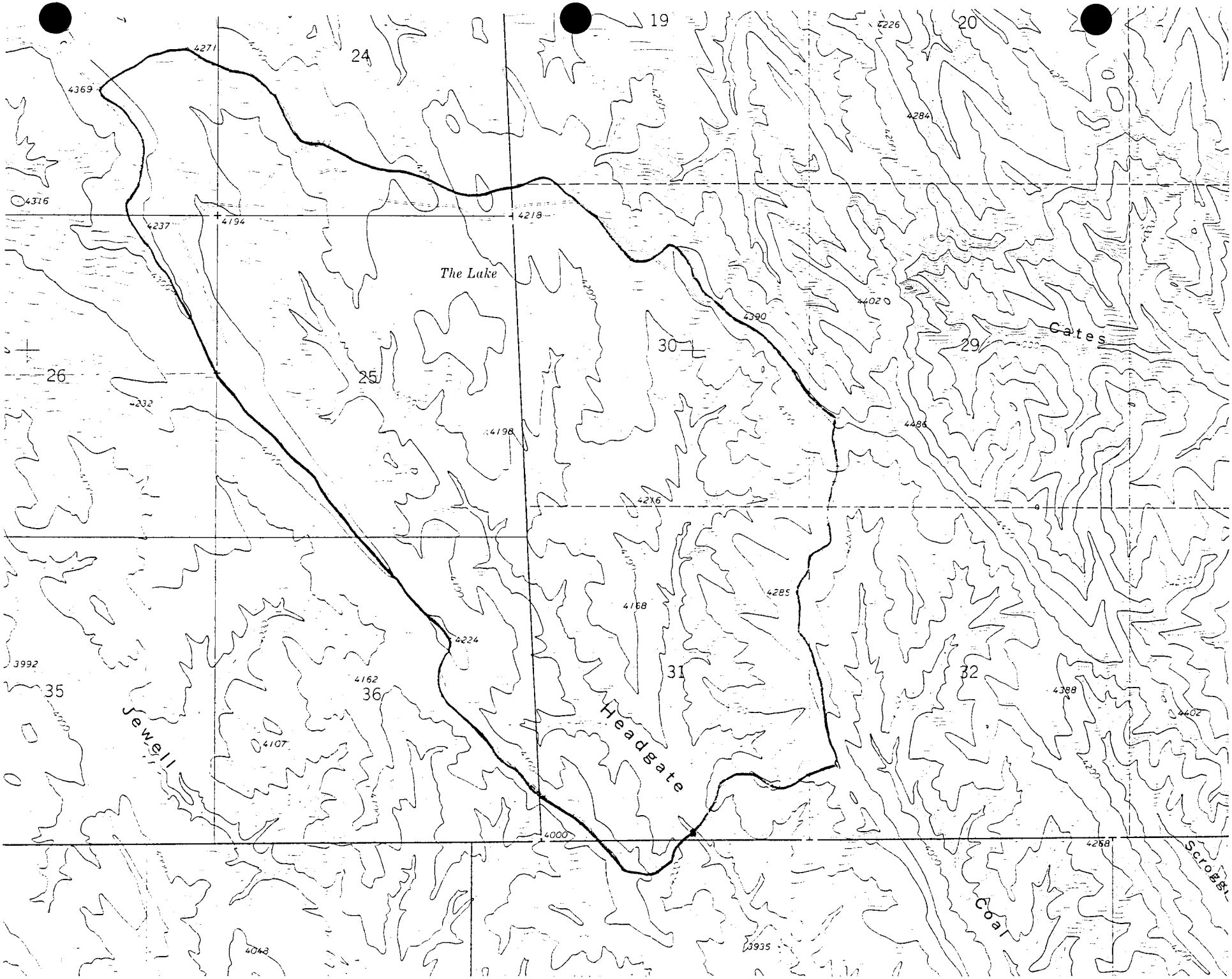
Flood Reconstitution for Wyoming Headgate Draw WHD1

Storm Event 16 July 69

Runoff: depth = .38 inches, Q_p = 1,670 cfs at t_p = .50 hours

$R_{recession}$ = .34 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
	0	1.39	5	D		1733	.50	.18	.26	.97	.12	Ø01	very short T_c


19
20
24
25
26
29
30
31
32
35
36
The Lake
Cates
Headgate
Jewell
Coal
Scroggs
4271
4369
4316
4237
4194
4218
4226
4284
4402
4390
4486
4232
4198
4216
4285
4168
4224
4162
4107
4388
4402
3992
4000
4268
4048
3935

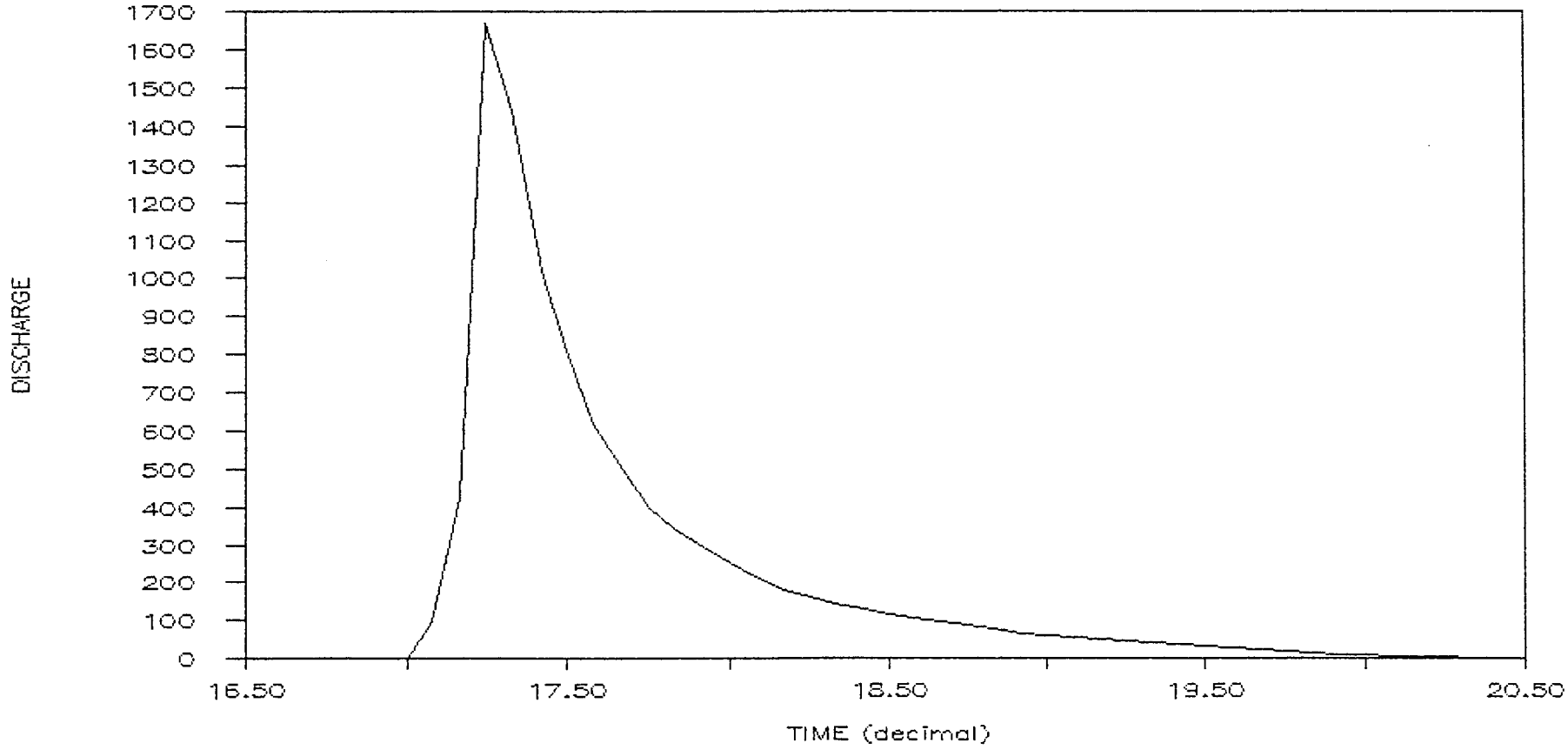
WYOMING DATA
HEADGATE DRAW AT UPPER

16 JUNE 1969

TIME	Q	P1	SUM P1
1645	0.00	0.00	0.00
1650	0.00	0.31	0.31
1655	0.00	0.31	0.62
1700	3.00	0.29	0.91
1705	95.00	0.29	1.20
1710	426.00	0.13	1.33
1715	1670.00	0.04	1.37
1720	1440.00	0.02	1.39
1725	1020.00	0.00	1.39
1730	810.00	0.00	1.39
1735	620.00	0.00	1.39
1740	500.00	0.00	1.39
1745	400.00	0.00	1.39
1750	346.00	0.00	1.39
1755	292.00	0.00	1.39
1800	254.00	0.00	1.39
1805	216.00	0.00	1.39
1810	180.00	0.00	1.39
1815	162.00	0.00	1.39
1820	145.00	0.00	1.39
1825	128.00	0.00	1.39
1830	117.00	0.00	1.39
1835	107.00	0.00	1.39
1840	97.00	0.00	1.39
1845	87.00	0.00	1.39
1850	77.00	0.00	1.39
1855	67.00	0.00	1.39
1900	62.00	0.00	1.39
1905	57.00	0.00	1.39
1910	52.00	0.00	1.39
1915	47.00	0.00	1.39
1920	42.00	0.00	1.39
1925	37.00	0.00	1.39
1930	32.00	0.00	1.39
1935	27.00	0.00	1.39
1940	22.00	0.00	1.39
1945	18.00	0.00	1.39
1950	14.00	0.00	1.39
1955	10.00	0.00	1.39
2000	8.00	0.00	1.39
2005	6.00	0.00	1.39
2010	5.00	0.00	1.39
2015	4.00	0.00	1.39
2020	3.00	0.00	1.39
2025	3.00	0.00	1.39
2030	0.00	0.00	1.39

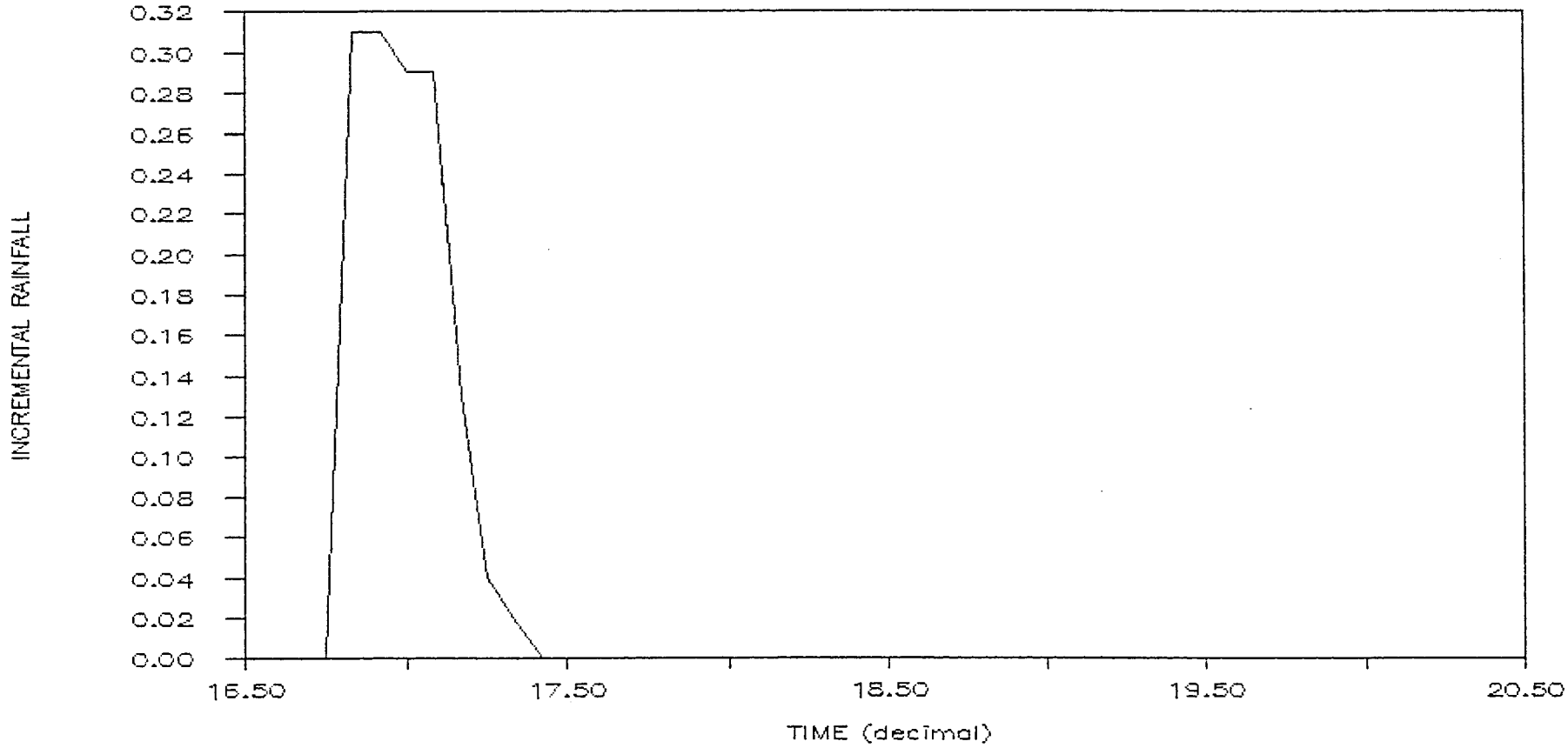
HEADGATE DRAW AT UPPER STATION

16 JUNE 1969



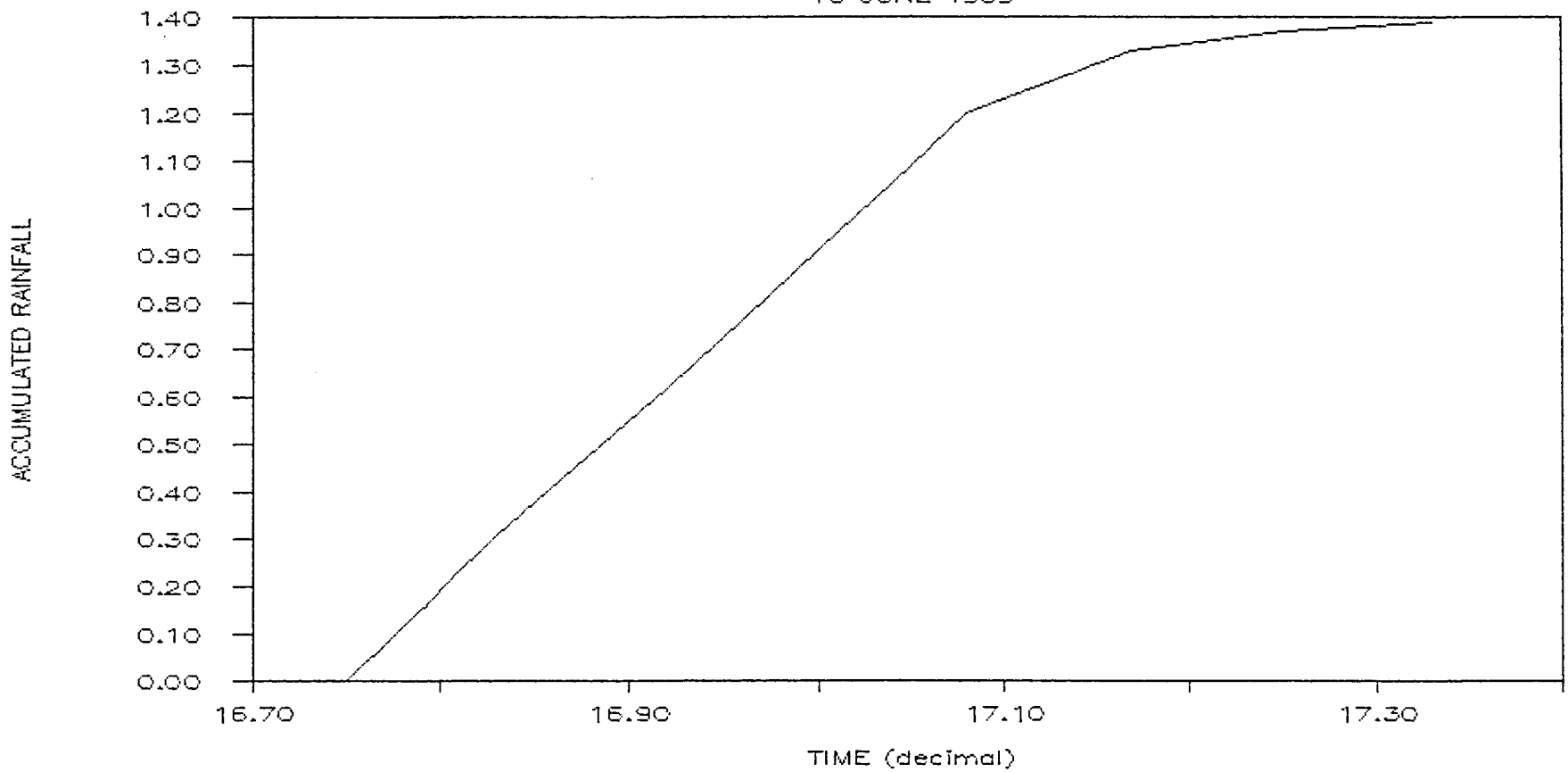
HEADGATE DRAW AT UPPER STATION

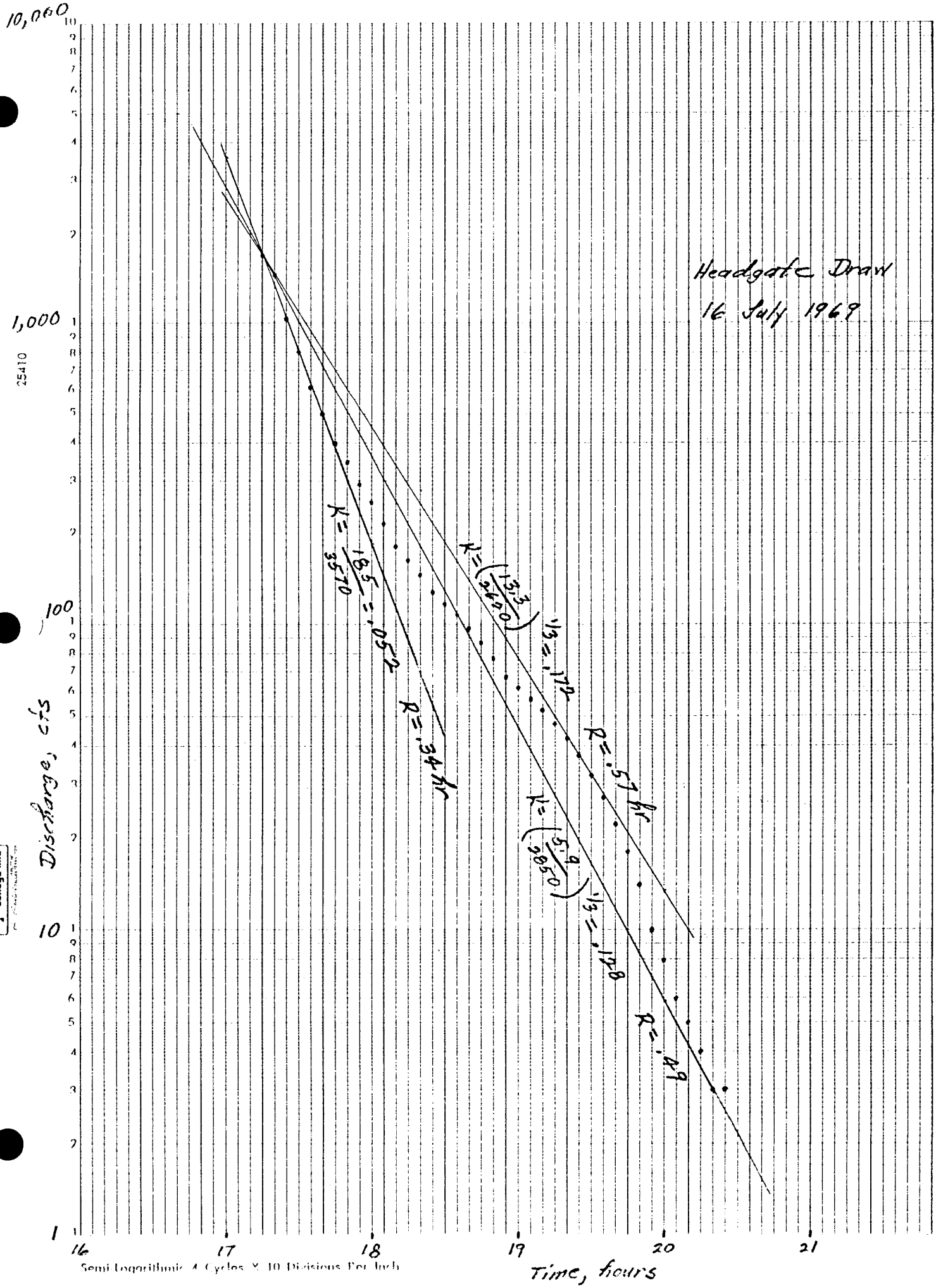
16 JUNE 1969



HEADGATE DRAW AT UPPER STATION

16 JUNE 1969




Headgate Draw
16 July 1969
K = 185/3570 = .052
R = .34 hr
K = (13.3/2400)
13 = .172
R = .57 hr
K = (5.9/2850)
13 = .128
R = .49
10,000
1,000
100
10
1
Discharge, cfs
16
17
18
19
20
21
Time, hours
Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch
25410

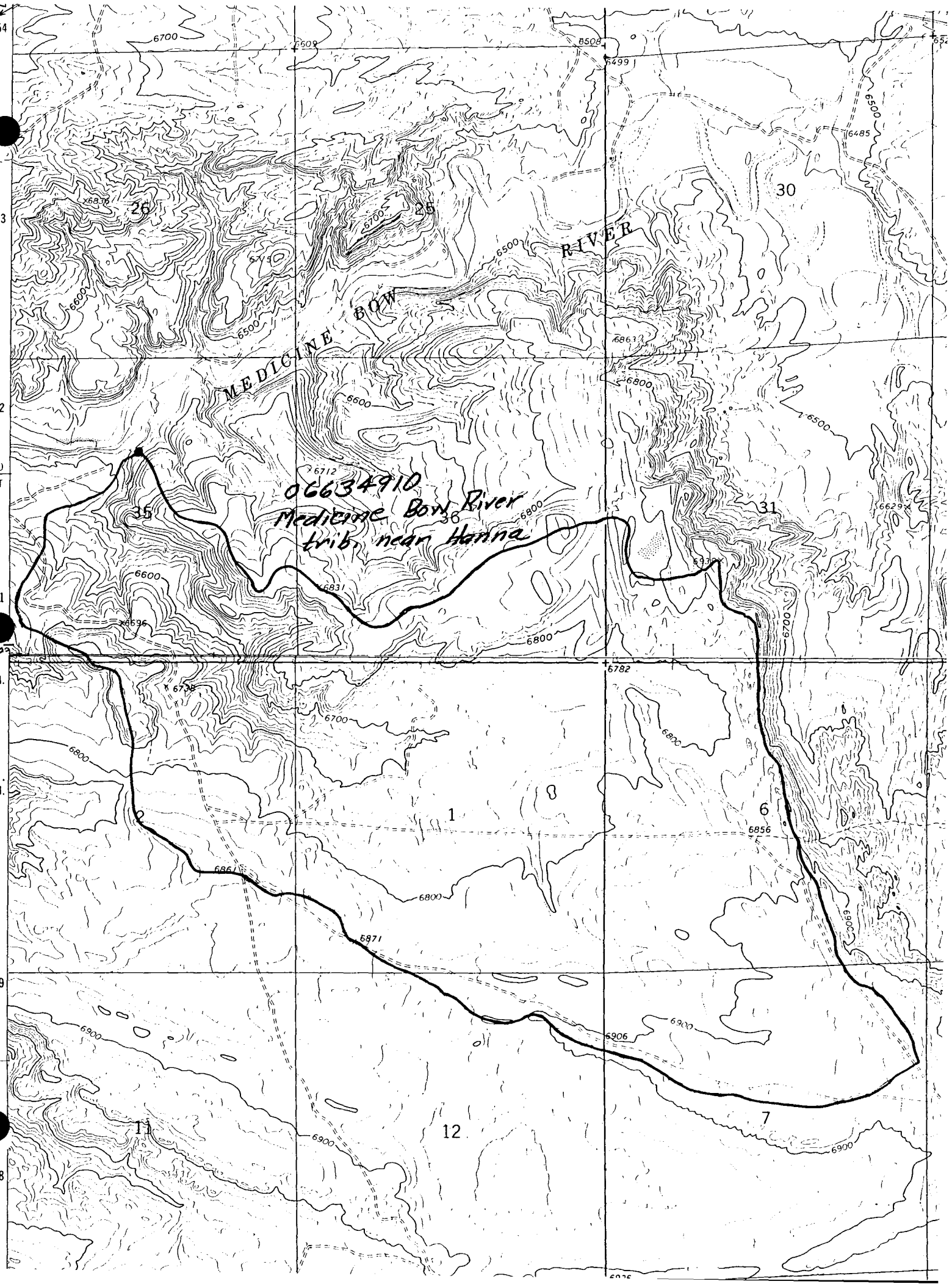
Flood Reconstitution for Wyoming Medicine Bow trib. WMB 1

Storm Event 28 June 73

Runoff: depth = .35 inches, Q_p = 679 cfs at t_p = 1.17 hours

$R_{recession}$ = .39 hrs

INPUT (1) Area acres	(2) Eff. Imp. Area %	(3) Rain in.	(4) Comp. Inter. min.	(5) Time-Area	(6)	Results (7) Q_p cfs	(8) t_p hr.	(9) T_c hr.	(10) R hr.	(11) STRTL in.	(12) CNSTL in/hr	(13) Output File	(14) Comment
1926.4	0	1.02	5	D		629	1.17	1.14	.38	.62	.11	Ø01	
"	"	"	"	comp.		623	1.17	1.04	.43	.64	.06	Ø02	← selected

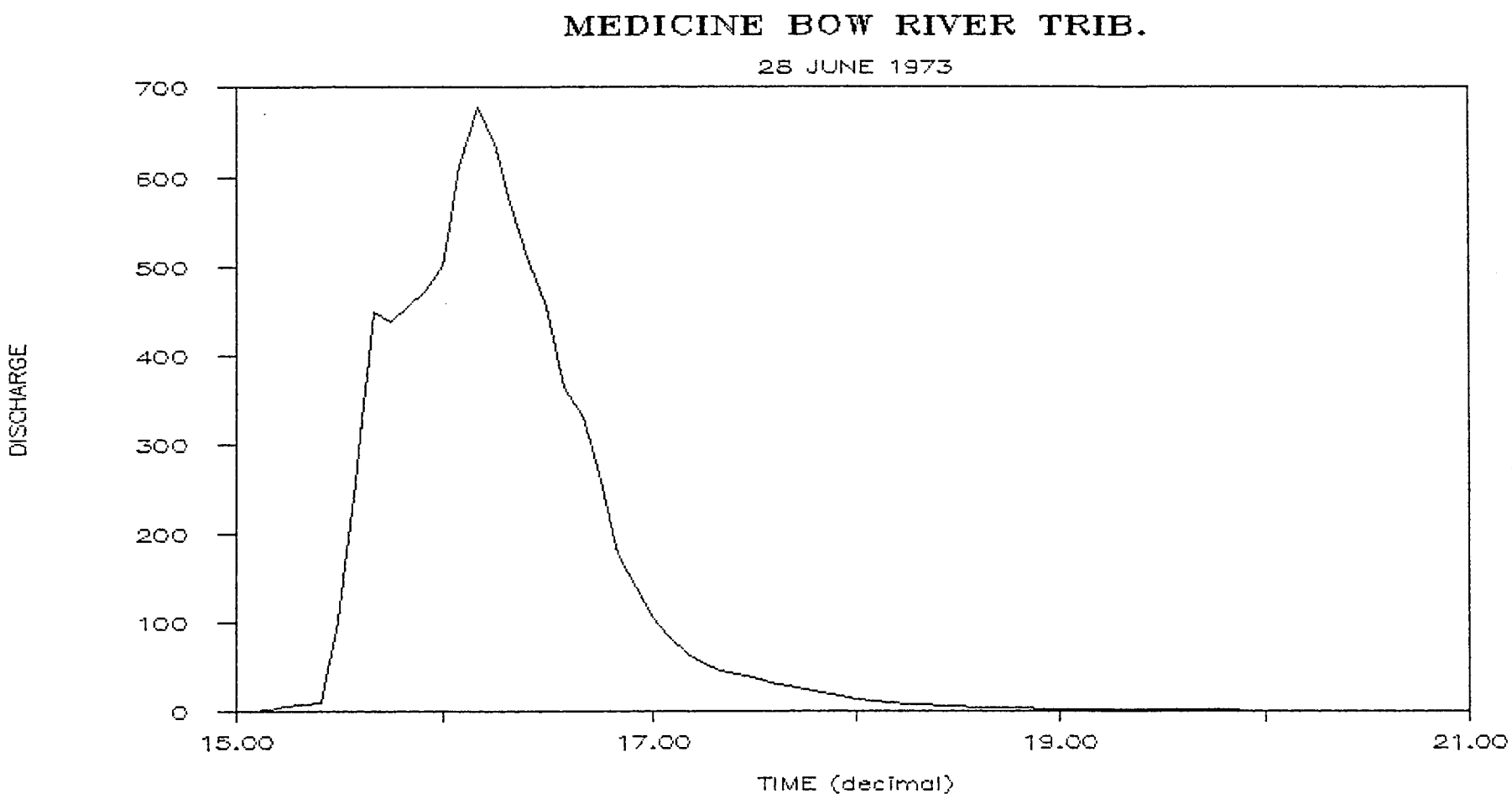

06634910
Medicine Bow River
trib. near Hanna
MEDICINE BOW RIVER
490 000
FEET
42°00'
T. 23 N.
50000m N.
4654
4653
4652
4651
4649
4648
26
25
30
35
36
31
1
6
7
11
12

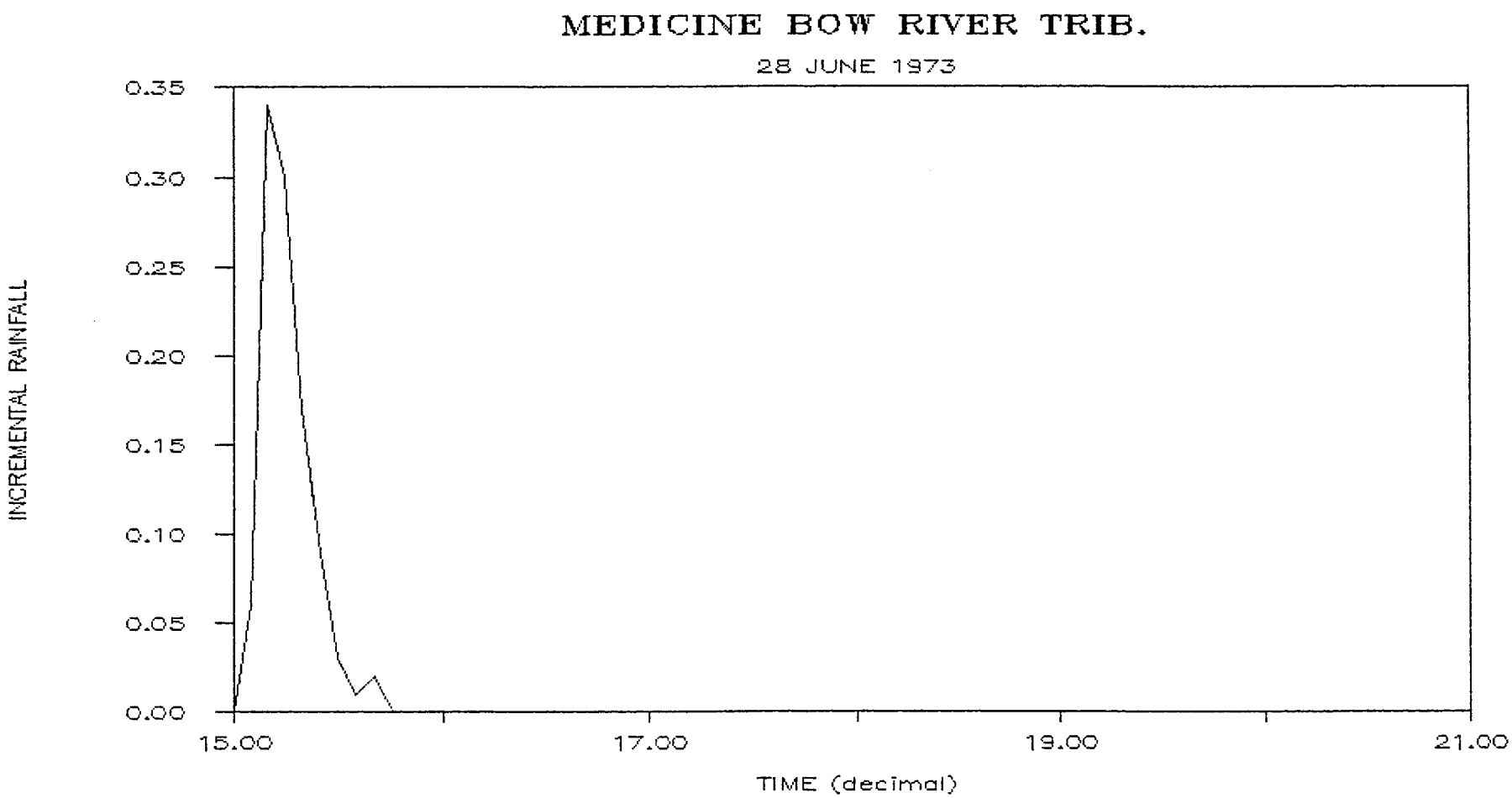
WYOMING DATA
MEDICINE BOW RIVER

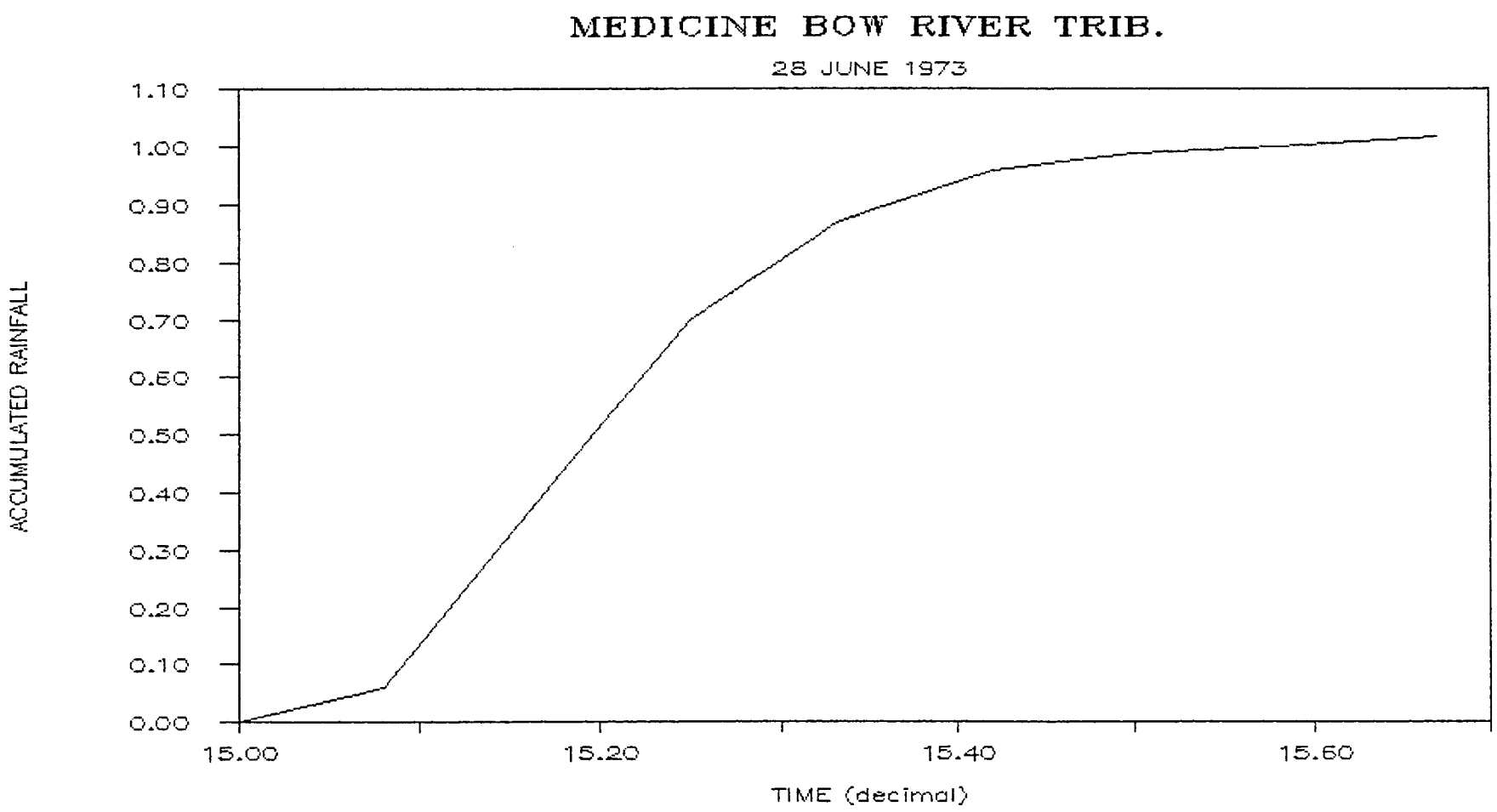
28 JUNE 1973

TIME	Q	P1	SUM P1
1500	0.00	0.00	0.00
1505	0.70	0.06	0.06
1510	2.00	0.34	0.40
1515	5.40	0.30	0.70
1520	7.40	0.17	0.87
1525	9.50	0.09	0.96
1530	103.00	0.03	0.99
1535	258.00	0.01	1.00
1540	448.00	0.02	1.02
1545	438.00	0.00	1.02
1550	454.00	0.00	1.02
1555	474.00	0.00	1.02
1600	502.00	0.00	1.02
1605	612.00	0.00	1.02
1610	679.00	0.00	1.02
1615	636.00	0.00	1.02
1620	572.00	0.00	1.02
1625	504.00	0.00	1.02
1630	454.00	0.00	1.02
1635	364.00	0.00	1.02
1640	331.00	0.00	1.02
1645	261.00	0.00	1.02
1650	177.00	0.00	1.02
1655	139.00	0.00	1.02
1700	105.00	0.00	1.02
1705	84.00	0.00	1.02
1710	64.00	0.00	1.02
1715	54.00	0.00	1.02
1720	45.00	0.00	1.02
1725	42.00	0.00	1.02
1730	38.00	0.00	1.02
1735	33.00	0.00	1.02
1740	29.00	0.00	1.02
1745	24.00	0.00	1.02
1750	21.00	0.00	1.02
1755	17.00	0.00	1.02
1800	14.00	0.00	1.02
1805	12.00	0.00	1.02
1810	10.00	0.00	1.02
1815	8.40	0.00	1.02
1820	7.20	0.00	1.02
1825	6.30	0.00	1.02
1830	5.40	0.00	1.02
1835	4.50	0.00	1.02
1840	4.00	0.00	1.02
1845	3.70	0.00	1.02
1850	3.50	0.00	1.02
1855	3.10	0.00	1.02
1900	2.80	0.00	1.02
1905	2.60	0.00	1.02
1910	2.50	0.00	1.02
1915	2.20	0.00	1.02

1920	2.00	0.00	1.02
1925	1.80	0.00	1.02
1930	1.70	0.00	1.02
1935	1.60	0.00	1.02
1940	1.50	0.00	1.02
1945	1.40	0.00	1.02
1950	1.40	0.00	1.02
1955	1.30	0.00	1.02
2000	1.20	0.00	1.02
2005	1.10	0.00	1.02
2010	1.10	0.00	1.02
2015	1.00	0.00	1.02
2020	0.90	0.00	1.02
2025	0.70	0.00	1.02
2030	0.60	0.00	1.02
2035	0.50	0.00	1.02
2040	0.40	0.00	1.02
2045	0.30	0.00	1.02
2050	0.20	0.00	1.02
2055	0.10	0.00	1.02
2100	0.00	0.00	1.02


MEDICINE BOW RIVER TRIB.
28 JUNE 1973
DISCHARGE
700
600
500
400
300
200
100
0
15.00
17.00
19.00
21.00
TIME (decimal)


MEDICINE BOW RIVER TRIB.
28 JUNE 1973
INCREMENTAL RAINFALL
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
15.00
17.00
19.00
21.00
TIME (decimal)


MEDICINE BOW RIVER TRIB.
28 JUNE 1973
ACCUMULATED RAINFALL
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
15.00
15.20
15.40
15.60
TIME (decimal)

MEDICINE BOW RIVER TRIBUTARY
28 JUNE 1973

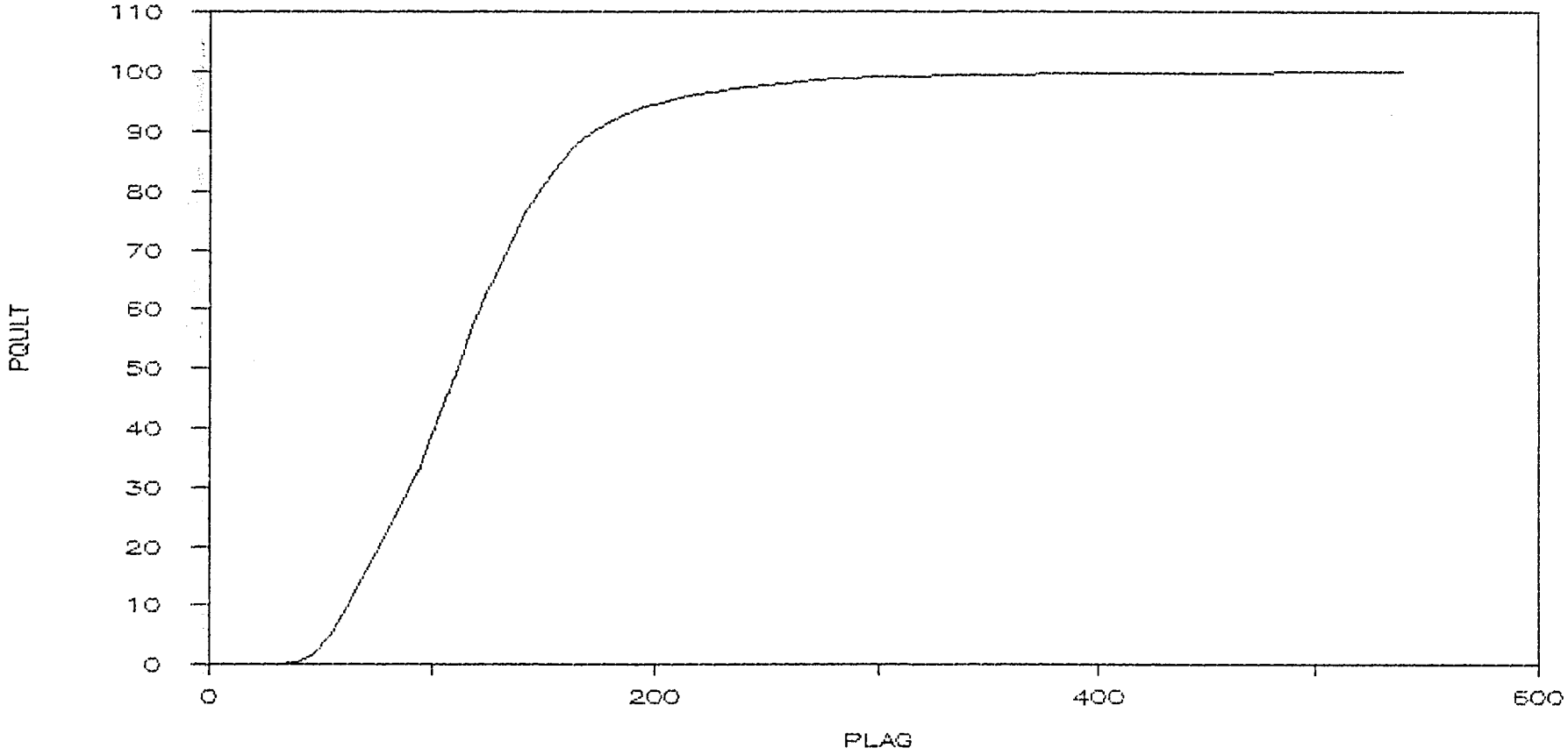
SUM Q	EUD	A	B
8100.00	0.35	11654.74	1289.21
LAG	QULT	C	G
1.07	23309.48	0.09	10543.94
		q1(F)	q2(E)
		1110.80	2400.01
		t1(H)	t2(X)
		0.33	0.42

TIME	Q	DEC TI	UHG	SUM UHG	PQULT	PLAG
1500	0.00	0.00	0.00	0.00	0.00	0.00
1505	0.70	0.08	2.01	2.01	0.01	7.50
1510	2.00	0.17	5.76	7.77	0.03	15.95
1515	5.40	0.25	15.54	23.31	0.10	23.45
1520	7.40	0.33	21.30	44.60	0.19	30.95
1525	9.50	0.42	27.34	71.94	0.31	39.40
1530	103.00	0.50	296.40	368.35	1.58	46.90
1535	258.00	0.58	742.45	1110.80	4.77	54.41
1540	448.00	0.67	1289.22	2400.01	10.30	62.85
1545	438.00	0.75	1260.44	3660.45	15.70	70.35
1550	454.00	0.83	1306.48	4966.93	21.31	77.86
1555	474.00	0.92	1364.04	6330.97	27.16	86.30
1600	502.00	1.00	1444.61	7775.58	33.36	93.80
1605	612.00	1.08	1761.16	9536.74	40.91	101.31
1610	679.00	1.17	1953.97	11490.71	49.30	109.75
1615	636.00	1.25	1830.23	13320.94	57.15	117.25
1620	572.00	1.33	1646.05	14966.99	64.21	124.76
1625	504.00	1.42	1450.37	16417.36	70.43	133.20
1630	454.00	1.50	1306.48	17723.84	76.04	140.70
1635	364.00	1.58	1047.49	18771.33	80.53	148.52
1640	331.00	1.67	952.52	19723.85	84.62	156.34
1645	261.00	1.75	751.08	20474.93	87.84	164.15
1650	177.00	1.83	509.36	20984.29	90.02	171.97
1655	139.00	1.92	400.00	21384.29	91.74	179.79
1700	105.00	2.00	302.16	21686.45	93.04	187.60
1705	84.00	2.08	241.73	21928.18	94.07	195.42
1710	64.00	2.17	184.17	22112.35	94.86	203.24
1715	54.00	2.25	155.40	22267.75	95.53	211.05
1720	45.00	2.33	129.50	22397.25	96.09	218.87
1725	42.00	2.42	120.86	22518.11	96.60	226.69
1730	38.00	2.50	109.35	22627.46	97.07	234.51
1735	33.00	2.58	94.96	22722.43	97.48	242.32
1740	29.00	2.67	83.45	22805.88	97.84	250.14
1745	24.00	2.75	69.07	22874.95	98.14	257.96
1750	21.00	2.83	60.43	22935.38	98.40	265.77
1755	17.00	2.92	48.92	22984.30	98.60	273.59
1800	14.00	3.00	40.29	23024.59	98.78	281.41
1805	12.00	3.08	34.53	23059.12	98.93	289.22
1810	10.00	3.17	28.78	23087.90	99.05	297.04
1815	8.40	3.25	24.17	23112.07	99.15	304.86
1820	7.20	3.33	20.72	23132.79	99.24	312.67
1825	6.30	3.42	18.13	23150.92	99.32	320.49
1830	5.40	3.50	15.54	23166.46	99.39	328.31
1835	4.50	3.58	12.95	23179.41	99.44	336.12
1840	4.00	3.67	11.51	23190.92	99.49	343.94
1845	3.70	3.75	10.65	23201.57	99.54	351.76
1850	3.50	3.83	10.07	23211.64	99.58	359.57
1855	3.10	3.92	8.92	23220.56	99.62	367.39
1900	2.80	4.00	8.06	23228.62	99.65	375.21

1905	2.60	4.08	7.48	23236.10	99.69	383.03
1910	2.50	4.17	7.19	23243.29	99.72	390.84
1915	2.20	4.25	6.33	23249.63	99.74	398.66
1920	2.00	4.33	5.76	23255.38	99.77	406.48
1925	1.80	4.42	5.18	23260.56	99.79	414.29
1930	1.70	4.50	4.89	23265.45	99.81	422.11
1935	1.60	4.58	4.60	23270.06	99.83	429.93
1940	1.50	4.67	4.32	23274.37	99.85	437.74
1945	1.40	4.75	4.03	23278.40	99.87	445.56
1950	1.40	4.83	4.03	23282.43	99.88	453.38
1955	1.30	4.92	3.74	23286.17	99.90	461.19
2000	1.20	5.00	3.45	23289.63	99.91	469.01
2005	1.10	5.08	3.17	23292.79	99.93	476.83
2010	1.10	5.17	3.17	23295.96	99.94	484.64
2015	1.00	5.25	2.88	23298.83	99.95	492.46
2020	0.90	5.33	2.59	23301.42	99.97	500.28
2025	0.70	5.42	2.01	23303.44	99.97	508.09
2030	0.60	5.50	1.73	23305.17	99.98	515.91
2035	0.50	5.58	1.44	23306.60	99.99	523.73
2040	0.40	5.67	1.15	23307.76	99.99	531.55
2045	0.30	5.75	0.86	23308.62	100.00	539.36
2050	0.20	5.83	0.58	23309.19	100.00	547.18
2055	0.10	5.92	0.29	23309.48	100.00	555.00
2100	0.00	6.00	0.00	23309.48	100.00	562.81

MEDICINE BOW RIVER TRIBUTARY

28 JUNE 1973

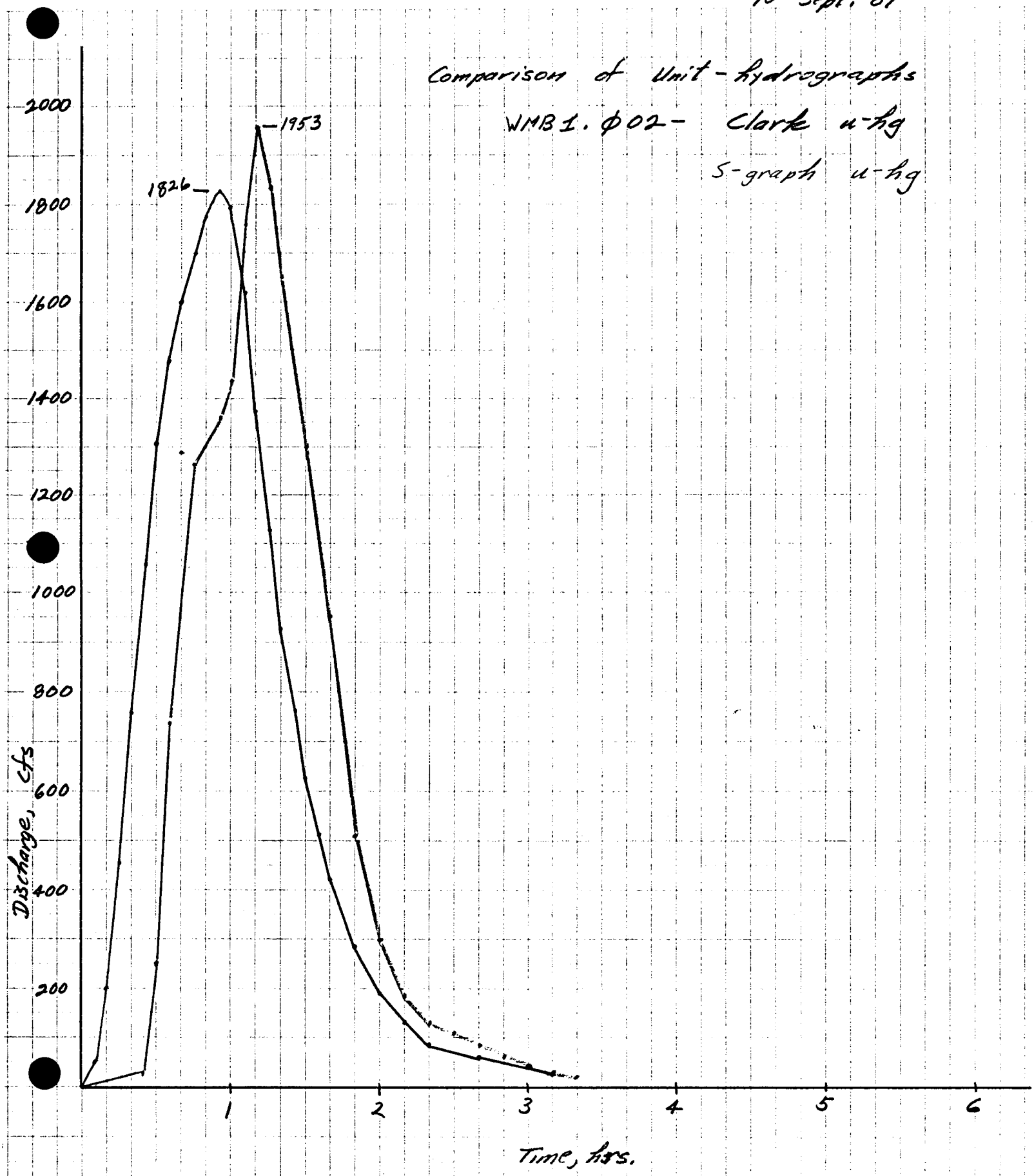


10 Sept. 87

Comparison of Unit-hydrographs

WMB1.Ø02- Clark u-hg

S-graph u-hg

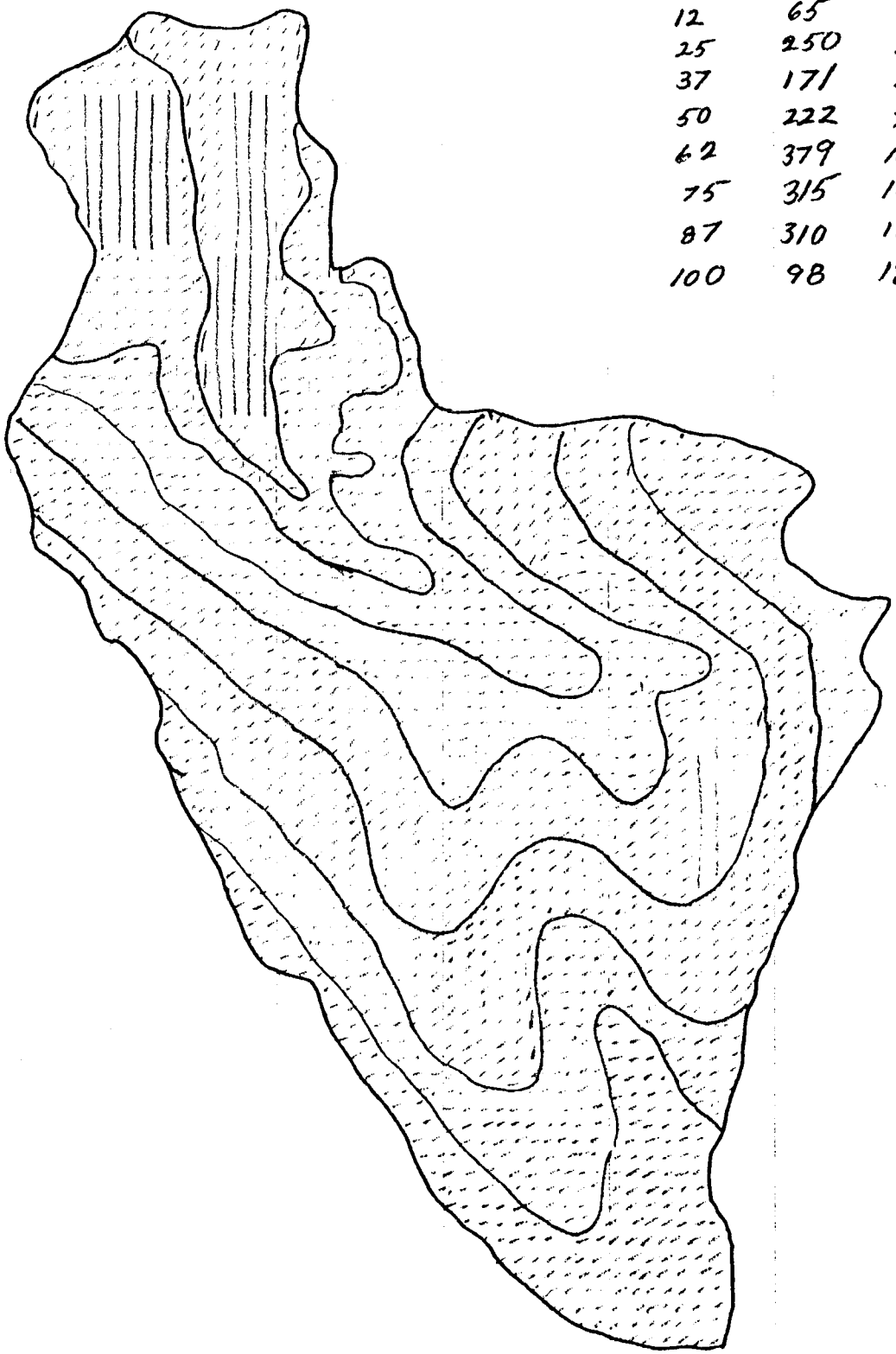


WMB

8 Sept. 87

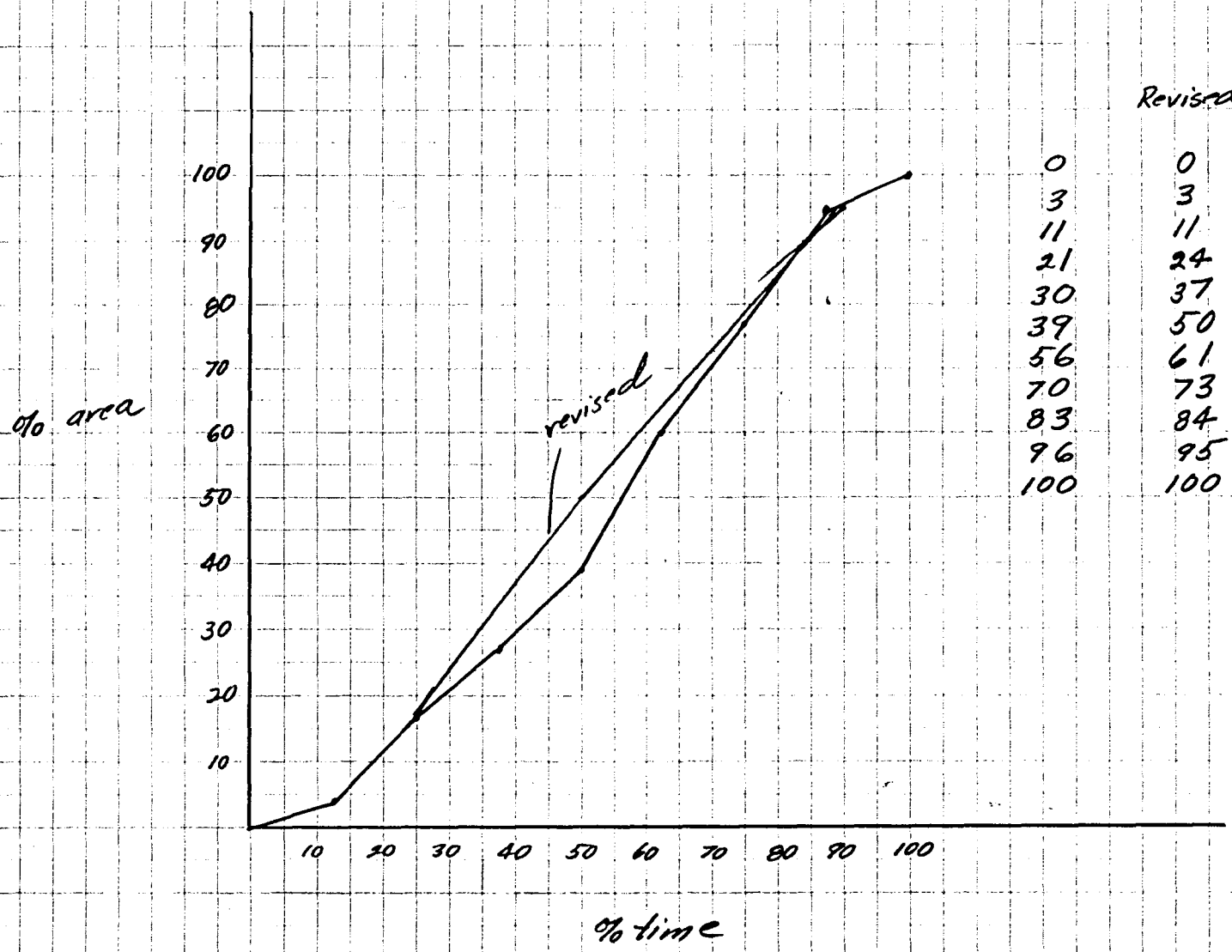
elev. gage — 6,280
elev. @ conc. pt. — 6,780) 500 ft
max. elev. — 6,939

% time			% area
0			0
12	65	65	4
25	250	315	17
37	171	486	27
50	222	708	39
62	379	1087	60
75	315	1402	77
87	310	1712	95
100	98	1810	100

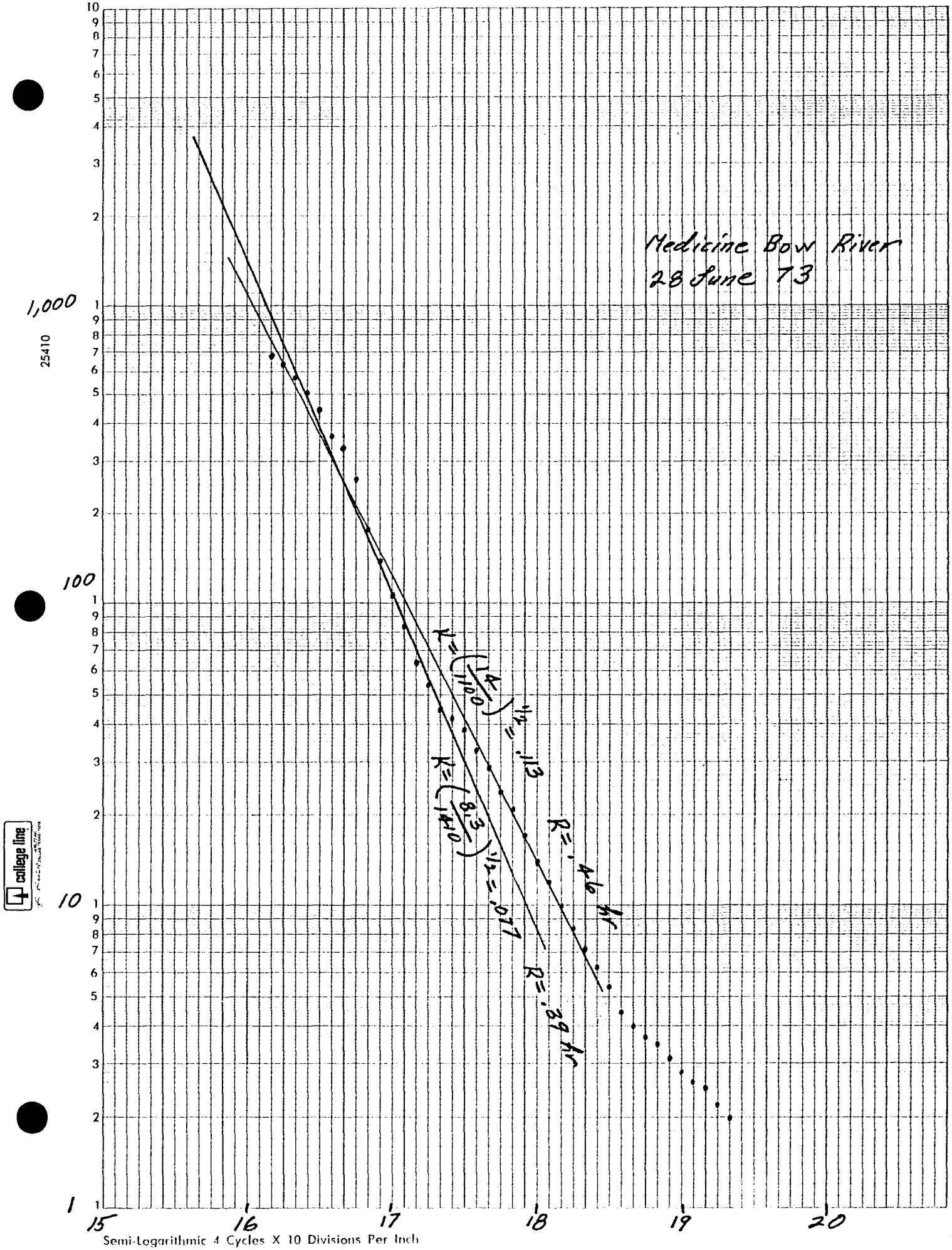


WMB

8 Sept 87



	Revised
0	0
3	3
11	11
21	24
30	37
39	50
56	61
70	73
83	84
96	95
100	100


Medicine Bow River
28 June 73
1,000
100
10
1
15
16
17
18
19
20
K = (14/1100)^1/2 = .113
K = (8.3/1410)^1/2 = .077
R = .46 hr
R = .39 hr
25410
Semi-Logarithmic 4 Cycles X 10 Divisions Per Inch

APPENDIX 3-I

Work sheets for time-area relations.

18 Aug 87

$$AI = 1.414\,T^{1.5} \qquad 0 \le T \le .5$$

$$AI = 1 - 1.414\,(1-T)^{1.5} \qquad .5 < T \le 1.0$$

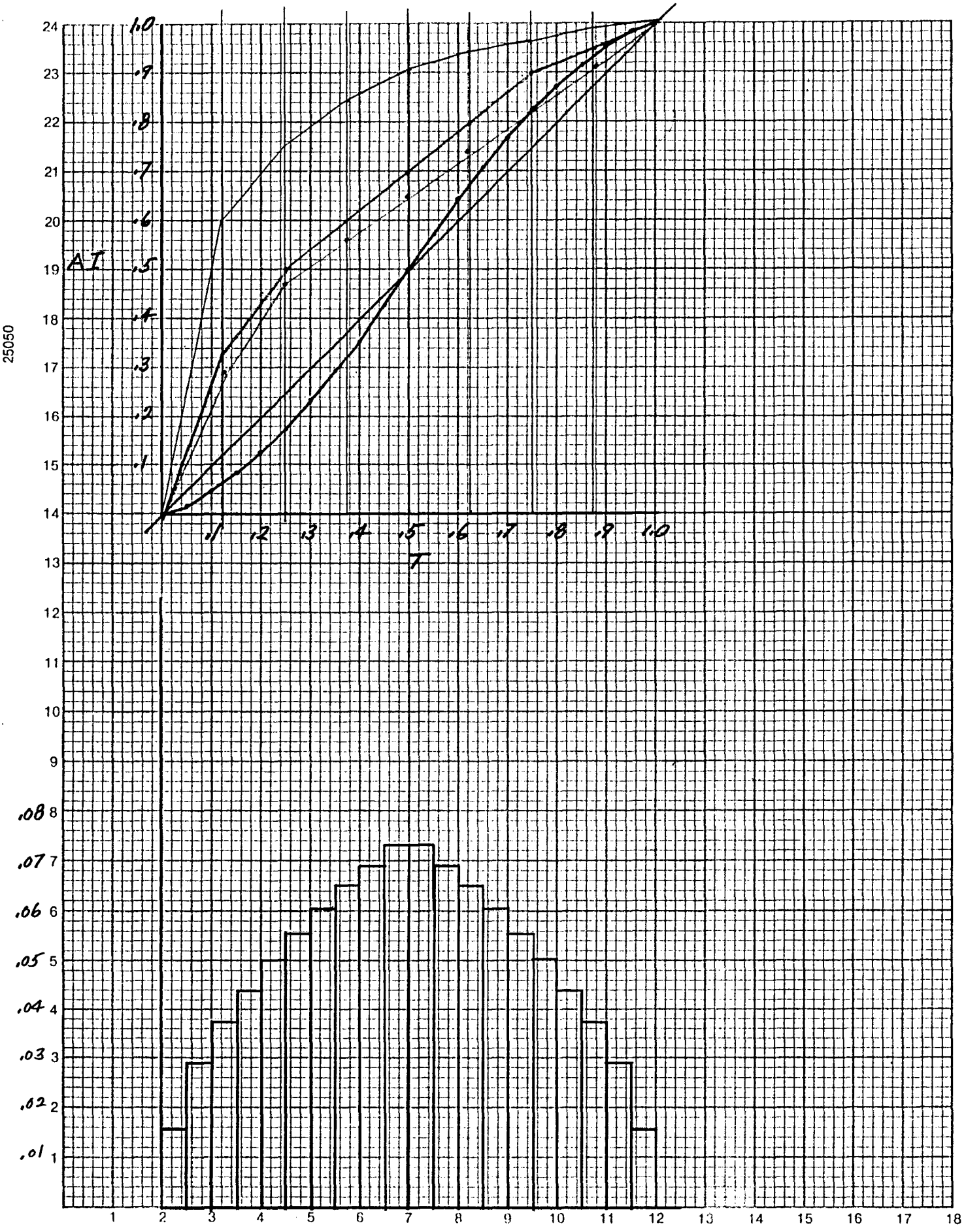
$$AI = \frac{\text{contributing area}}{\text{total area}}$$

$$T = \frac{\text{travel time for contributing area}}{\text{time of concentration}}$$

T	AI	ΔAI
0.0	0.0	.0158
.05	.0158	.0289
.1	.0447	.0374
.15	.0821	.0444
.2	.1265	.0503
.25	.1768	.0555
.3	.2323	.0605
.35	.2928	.0649
.4	.3577	.0691
.45	.4268	.0732
.5	.5	.0732
.55	.5732	.0691
.6	.6423	.0640
.65	.7072	.0605
.7	.7677	.0556
.75	.8233	.0502
.8	.8735	.0444
.85	.9179	.0374
.9	.9553	.0289
.95	.9842	.0158
1.00	1.0	

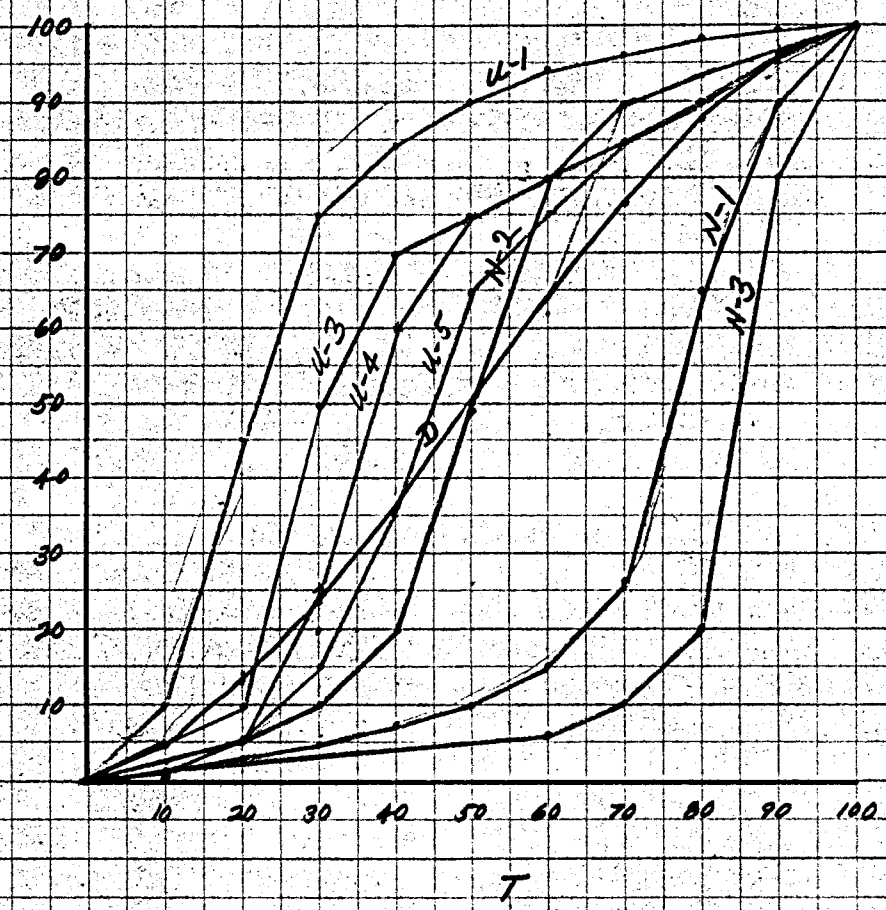
T	AI
0	
.125	.0625
.25	.1768
.375	.3247
.5	.5
.625	.6753
.75	.8233
.875	.9375
1.0	1.0

18 Aug 87



5 Squares To The Centimeter

28 Aug 87



T	D	U-1	U-3	N-1	N-2	N-3	U-4	U-5	U-6	N-4
0	0	0	0	0	0	0	0	0	0	0
10	4.5	10	5	2	3	1	1	1	1	4
20	12.6	45	10	3	5	2	5	5	3	13
30	23.2	75	50	5	10	3	25	15	10	50
40	35.8	84	70	7	20	4	60	35	35	80
50	50.	90	75	10	50	5	75	65	50	90
60	64.2	94	80	15	80	6	80	75	64	92
70	76.8	96	85	25	90	10	85	85	77	94
80	87.4	98	90	65	94	20	90	90	87	96
90	95.5	99	95	90	97	80	95	95	96	98
100	100.	100	100	100	100	100	100	100	100	100

For small watersheds (< 50 acres) with 5-minute data, there is no improvement in results in inputing a time-area table. This is because the T_c is so small that the area relation (instantaneous u-hg) is a uniform distribution.

APPENDIX 3-J

Time of Concentration in Small Rural Watersheds, Papadakis, C.N., and Kazan, M.N., Presented at the 1986 ASAE Engineering Hydrology Symposium, Williamsburgh, VA, August 1986.

George V. Sabol

TIME OF CONCENTRATION IN SMALL RURAL WATERSHEDS

by

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Cincinnati, Ohio

August 1986

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TIME OF CONCENTRATION IN SMALL RURAL WATERSHEDS

1.0 INTRODUCTION

The determination of peak discharges for a given return period is necessary for the appropriate design of drainage structures. Peak discharges of a given frequency are related to rainfall intensity which in turn depends on rainfall duration. Since the maximum runoff for a given frequency occurs when the rainfall duration becomes equal to the time of concentration of the watershed, the time of concentration is the most significant variable in the computation of peak runoff.

Many empirical and a few theoretically founded equations used to compute the time of concentration were evaluated in this study. Some of these equations consider the time of concentration to be only a function of physical watershed parameters, such as length, slope, roughness and degree of imperviousness. Other equations also consider the characteristics of rainfall excess, such as rainfall intensity and duration. Times of concentration computed by these equations for a given watershed and for the same rainfall event were found to vary by more than 500%.

Data were gathered and analyzed from: (a) measurements from tests on three experimental watersheds conducted by the Corps of Engineers. Colorado State University, and the University of Illinois and from (b) measurements from 84 small rural watersheds from 22 states obtained by the USDA Agricultural Research Service for selected runoff events. From this data, two global regression equations were developed for the estimation of the time of concentration in small rural watersheds. One of these equations is based on four independent parameters and the second is based on only one independent parameter. These equations have general applicability and could be used in design with a good degree of confidence.

2.0 REVIEW OF EXISTING METHODS

The first phase of this study involved an exhaustive literature search which revealed a plethora of methods developed to compute the time of concentration. These formulas share the general format:

$$T_c = k\, L^a\, n^b\, S^{-y}\, i^{-z} \qquad (1)$$

where T_c = Time of concentration, in minutes
L = Length of flow path, in feet
n = Roughness coefficient (See Section 4.2)
S = Average slope of flow path, in ft/ft
i = Intensity of excess rainfall, in in/hr (See Section 4.3)
k = Constant
a, b, y, z = Exponents

In some cases $b = 0$ and/or $z = 0$ which indicates that the time of concentration was considered to be independent of watershed surface roughness and/or excess rainfall intensity. Eleven of the most commonly encountered formulas used in computing the time of concentration are summarized below:

a. Kirpich (1940) [8,9]

$$T_c = 0.0078\, L^{0.77}\, S^{-0.385} \qquad (2)$$

b. Izzard (1946) [8]

$$T_c = 41\, L^{0.33}\, (0.0007\, i + C_i) S^{-0.333}\, i^{-0.667} \qquad (3)$$

Type of Surface	Retardance Coef. C_i
Very smooth pavement	0.007
Concrete pavement	0.012
Dense grass	0.060

c. Kerby/Hathaway (1959) [6,7,8] (4)

$T_c = 0.827\ L^{0.467}\ n_k^{0.467} S^{-0.233}$

Type of Surface	Average Surface Retardance n_k
Smooth impervious surfaces	0.02
Smooth bare packed soil	0.10
Poor grass, cultivated row crops or moderately rough bare surface	0.20
Pasture or average grass	0.40
Deciduous timberland	0.60
Conifer timberland, deciduous timberland with deep forest litter or dense grass	0.80

d. Carter (1961) [10,15] (5)

$T_c = L^{0.6}\ C_c\ S^{-0.3}$

where C_c = retardance coefficient equal to 0.045 for pristine conditions

e. Eagleson (1962) [15] (6)

$T_c = (L\ L_{ca})^{0.38}\ C_e\ S^{-0.19}$

Type of Surface	Retardance Coefficient C_e
Mountain drainage	0.178
Foothill drainage	0.107
Valley drainage	0.052
Urban drainage	0.027

f. Kinematic Wave Equation reported by Henderson and Wooding (1964), Ragan and Duru (1972), and Aron (1973), [8]

$$T_c = 0.94\, L^{0.6}\, n^{0.6}\, S^{-0.3}\, i^{-0.4} \qquad (7)$$

Type of Surface	Manning Roughness Coefficient n for flood plains [3]
Smooth impervious surface	0.01-0.02
Smooth bare packed soil, (no crop)	0.02-0.04
Poor grass, moderately bare surface	0.025-0.035
Gravels, Cobbles	0.03-0.05
Pasture or average grass cover	0.03-0.05
Mature field crops	0.03-0.05
Light brush and trees	0.04-0.08
Dense brush	0.07-0.16
Dense willows, dense grass, forest	0.11-0.20

g. Morgali and Linsley (1965) [11]

$$T_c = 0.99\, L^{0.593}\, n^{0.605}\, S^{-0.38}\, i^{-0.388} \qquad (8)$$

where n = Manning's roughness coefficient

h. Federal Aviation Agency, FAA (1970) [8,10]

$$T_c = 0.39\, L^{0.5}\, (1.1 - C)\, S^{-0.333} \qquad (9)$$

where C = rational method runoff coefficient

Type of Surface	Value of C
Concrete, asphalt	0.80 - 0.95
Drives and walks	0.75 - 0.85
Business districts and local areas	0.50 - 0.70
Residential single family areas	0.35 - 0.45
Res. with 1/2 acre lots or larger	0.25 - 0.40
Parks, cemeteries	0.10 - 0.25
Unimproved areas	0.10 - 0.30

i. SCS Curve Number (1975) [8,20]

$$T_c = \frac{1}{190} L^{0.8} \left(\frac{1000}{CN} - 9\right)^{0.7} S^{-0.5} \qquad (10)$$

Type of Surface	SCS Runoff Curve Number CN
Paved areas	95 - 98
Cultivated land (soil group B&C)	80 - 90
Pasture or range land	70 - 80
Meadow (good condition), (A30)	60 - 70
Wood or forest: thin stand, poor cover	65 - 75
good cover, (A 25)	55 - 70
Lawns, parks, cemeteries	
grass cover 75 % or more	60 - 75
grass cover 50% to 75%	70 - 80
Surface mined basins: raw spoils	88
graded spoils	84
top-dressed spoils	82
vegetated spoils	75

j. SCS Velocity Charts [20] $T_c = \frac{1}{60} \frac{L}{V}$

where V = average velocity in fps obtained from charts in TR55 [20]. From the same reference $V = \sqrt{S}/C_v$ where C_v = retardance factor. Therefore:

$$T_c = \frac{1}{60} L C_v S^{-0.5} \qquad (11)$$

Type of Surface	Retardance Factor C_v
Paved area and shallow gutter flow	0.05
Grassed waterway	0.06
Nearly bare ground	0.10
Short grass pasture and lawns	0.14
Fallow or minimum tillage cultivation	0.21
Forest, with heavy ground litter and meadow	0.40

k. Singh's Kinematic Wave and Chezy Formula (1976) [19]

$$T_c = 0.58\, L^{0.667}\, C_s^{-0.667}\, S^{-0.333}\, i^{-0.333} \qquad (12)$$

Type of Surface	Chezy's Roughness Coefficient C_s
Smooth impervious surface	50 - 100
Smooth bare packed soil	25 - 50
Poor grass, moderately bare surface	30 - 40
Gravels, cobbles	20 - 30
Pasture or average grass cover	20 - 30
Mature field crops	20 - 30
Light brush and trees	12 - 25
Dense brush	6 - 14
Dense willows, dense grass, forest	5 - 9

3.0 APPLICATION OF EXISTING FORMULAS

Three rural watersheds were chosen to compare the time of concentration as computed by eleven different formulas. The three watersheds have areas of 3.6 acres, 59 acres and 187 acres respectively. During the rainfall events that were selected, both precipitation and runoff were measured by the US Department of Agriculture, Agricultural Research Service.

3.1 Case Study I

A small rural watershed was selected in Hastings, Nebraska. The watershed has an area of 3.62 acres, a length of flow path of 480 feet, and an average path slope of 0.075. The plan view of the watershed is shown in Figure 1. The surface of the watershed was native grass meadow 14 inches high and heading and in excellent condition. The rainfall event of June 16, 1957 was selected and the measured rainfall hyetograph and resulting runoff hydrograph are presented in Figure 2. The average excess rainfall intensity was found to be equal to 1.7 in/hr and the lag time was measured equal to 6.5 minutes (Figure 2). Therefore, the actual time of concentration was found to be equal to 10.8 minutes.

Eleven formulas were employed to compute the time of concentration of this basin and the results are summarized in Table 1. It is important to note that the minimum time of concentration of 2.5 minutes was computed using the Kirpich equation. The maximum time of concentration of 16.5 minutes was computed by the Kerby equation. This amounts to a discrepancy of over 600% between minimum and maximum computed times of concentration.

3.2 Case Study II

A 59.2 acre natural watershed was selected near Americus, Georgia. The basin has a flow path length of 3,380 feet with an average slope of 0.0035. The plan view of the watershed is shown in Figure 3. The basin surface consisted of 84% oats in the dough stage, 6% peanuts in good stand, 6% sand clay road, and 4% idle weeds and grass. The rainfall event of August 19, 1942 was selected and the measured rainfall hyetograph and resulting runoff hydrograph are presented in Figure 4. The average excess rainfall intensity was found equal to 1.01 in/hr and the lag time was measured equal to 40 minutes (Figure 4). Therefore, the actual time of concentration was found to be 67 minutes.

Eleven formulas were employed to compute the time of concentration of the basin and the results are summarized in Table 1. The minimum times of

concentration of 32 and 36 minutes were computed using the Carter and Kirpich formulas respectively. The maximum time of concentration of 175 minutes was computed by the SCS Curve Number method. There is a difference of over 500% between minimum and maximum computed times of concentration.

3.3 Case Study III

A natural watershed with an area of 187 acres was selected near Hamilton, Ohio. The basin has a flow path length of 5,000 feet with an average slope of 0.013. The plan view of the watershed is shown in Figure 5. The surface of the basin comprised 25% row crops, 53% grassland or mature small grain, and 22% woods and miscellaneous uses. The rainfall event of May 17, 1943 was selected and the measured rainfall hyetograph and resulting runoff hydrograph are presented in Figure 6. The average excess rainfall intensity was found equal to 4.95 in/hr and the lag time was measured equal to 16 minutes (Figure 6). Therefore, the actual time of concentration was found to be 27 minutes.

Eleven formulas were employed to compute the time of concentration of the basin and the results are summarized in Table 1. The minimum times of concentration of 27 and 29 minutes were computed again by the Carter and Kirpich formulas respectively. The maximum time of concentration of 94 minutes was computed by the FAA equation. There is a difference of over 300% between computed minimum and maximum times of concentration.

It is important to note that in the above three case studies the Kirpich equation and the Carter equation consistently produced the lowest values of the time of concentration.

4.0 TIME OF CONCENTRATION OF NATURAL WATERSHEDS

4.1 Data Base

A comprehensive data base was compiled for 84 natural rural watersheds from 22 states. Table 2 lists the number of sites selected in each state. Information was obtained from the US Department of Agriculture, Agricultural Research Service [1]. Watersheds were selected only if:

a) they had an area of less than 500 acres,
b) detailed basin topography and surface cover information was available, and
c) a rainfall event had been isolated with good rainfall-runoff measurements.

The length of the flow path L in feet, and the average slope of the flow path S were measured for each watershed and are listed in Table 3. Values of the other two independent parameters, the average surface roughness coefficient n of the basin, and the excess rainfall intensity i in inches/hour, were estimated from the available data according to the procedures outlined below and they are presented in Table 3. Values of the time of concentration T_c were also found from the available data according to the procedure outlined in Section 4.4 and are listed for each watershed in Table 3.

4.2 Roughness Coefficient Estimation

Different depths of flow usually result in different values of roughness coefficient for the same surface roughness. Table 4 provides a comparison between roughness coefficients proposed by V.T. Chow [3] for floodplains (wide channel), roughness coefficients proposed by MITCAT [21] and those proposed by Pennsylvania State University for surface flows [8]. Because of relative roughness effects, the roughness coefficient associated with surface sheet flow is larger than that associated with channel flow over the same surface.

The flow path in a rural watershed is a combination of overland flow and channel flow. The larger the watershed, the larger is the portion of channel flow; therefore, for the same surface roughness, the average roughness coefficient should decrease with increasing area. This relationship for a variety of surface covers is depicted graphically in Figure 7. Values of the roughness coefficient recommended by MITCAT [21] and Pennsylvania State University [8] for predominantly overland flow in small watersheds were adapted in Figure 7. For predominantly channel flow in large watersheds, values of the roughness

coefficient suggested by Chow [3] were utilized. Figure 7 was used to estimate the roughness coefficients listed in Table 3 for the 84 rural watersheds.

4.3 Excess Rainfall Intensity Estimation

The area enveloped by a hydrograph curve and the horizontal time-axis represents volume of runoff. This runoff is the result of the excess rainfall that generated the hydrograph. The portion of the rainfall hyetograph that corresponds to the excess rainfall can be determined by finding the volume of total runoff and equating volumes, as shown in Figure 8. The remaining portion of the hyetograph is considered to be rainwater lost to infiltration, retention and evaporation.

The time of excess rainfall, T_r, can be estimated from the rainfall excess portion of the hyetograph. The average excess rainfall intensity is found by dividing the volume of excess rainfall (or the total runoff volume in inches) by the time of excess rainfall. This procedure is approximate, but is simple to use and sufficiently accurate for the ensuing analysis.

Table 3 lists excess rainfall intensities computed according to the procedure outlined above for selected precipitation events recorded by the USDA Agricultural Research Service in 84 rural watersheds across the United States.

4.4 Time of Concentration Estimation

The time of concentration, T_c, is defined as the time from the beginning of excess rainfall needed for the watershed point most hydraulically remote from the basin outlet, to contribute to the runoff at the outlet.

Other time parameters that are shown in Figure 9 are defined as follows:

i) Time to Peak, T_p, is the time from the beginning of the excess rainfall to the peak runoff.

ii) Lag time, T_l, is the time from the center of mass of the excess rainfall to the peak runoff. The lag time is equal to $T_l = T_p - 0.5\,T_r$.

iii) Time of Equilibrium, T_e, is the time from the beginning of excess rainfall needed for the runoff rate (in in/hr) to reach the excess rainfall intensity. This occurs for large times of excess rainfall, T_r, when $T_r \geq T_c$.

The sketches in Figure 9 depict two types of hydrographs, those that reach equilibrium and the non-equilibrium hydrographs that exhibit a peak discharge. The time of concentration is estimated differently for each of those two cases:

a) Hydrographs reaching equilibrium state. These hydrographs exhibit a maximum discharge platform. If the beginning of the platform is well defined, then the time of concentration $T_c = T_e$ is the time from the start of the excess rainfall to the beginning of the maximum discharge platform. If the beginning of this platform is not well defined, the point corresponding to 97% of the maximum observed discharge was assumed to represent the beginning of the platform.

b) Hydrographs with peak discharge, not reaching equilibrium. In this case the time of concentration is considered to be equal to the lag time divided by 0.6 as proposed by the Soil Conservation Service:

$$T_c = T_l \ /0.6 = (T_p - 0.5\,T_r)/0.6 \qquad (13)$$

The times of concentration, T_c, of 84 rural watersheds were computed for selected excess rainfall intensities, using the procedure outlined above and values obtained are listed in Table 3, together with the corresponding times to peak, and lag times or times of equilibrium.

5.0 TIME OF CONCENTRATION OF EXPERIMENTAL WATERSHEDS

5.1 Corps of Engineers Experimental Results

The Corps of Engineers conducted from 1948 to 1952 simulated rainfall tests at the Santa Monica Municipal Airport. The tests were performed on airfield strips having flow-path lengths of 84 to 500 feet and slopes of 0.5, 1 and 2 percent. Simulated rainfall intensities of 0.25 to 10 inches per hour on concrete and simulated turf were utilized. The roughness coefficient for concrete surfaces was considered equal to n = 0.04 and for the turf covered flow surfaces equal to n = 0.20. The results of 162 of these tests as compiled by the Los Angeles District of the Corps of Engineers [2] were used in this study. The length of the flow path, the slope, the applied rainfall intensity, and the measured average time of equilibrium (equal to the time of concentration) are listed in Table 5 for each of 89 cases involving concrete surface and in Table 6 for each of 73 cases involving simulated turf surface.

5.2 Colorado State University Experimental Results

The experimental watershed constructed at the Engineering Research Center of Colorado State University consists of a conic sector which has an interior angle of 104 degrees and a radius of 116 feet with a slope of 0.05. Two 88-foot by 70-foot long intersecting plane surfaces joint the edges of the conic sector with a maximum surface slope of 0.05 and a collecting channel slope of 0.03 [15]. The simulated rainfall tests were conducted in 1970-1971 and utilized different surface cover materials,such as gravel and butyl.

Ninety three of these tests are summarized in Table 7 including the identification of the experimental run, watershed configuration, length of flow-path, slope and rainfall intensity. The Manning's roughness coefficients and the actual times of concentration were estimated according to the criteria established in Section 4.0 and are listed in Table 7.

5.3 University of Illinois Experimental Results.

An experimental basin and a precipitator were used in an indoors laboratory in the University of Illinois at Urbana-Champaign. The size of the basin is 40 feet by 40 feet, its lateral slope is 0.01 and its longitudinal slope can be set at 0.005, 0.01, or 0.03. The length of the flow path is 60 feet and the roughness coefficient of the aluminum plate surface of the basin was estimated equal to n = 0.08. The results of

the tests performed in 1974 at the University of Illinois were reported using relative nondimensional variables [17]. The necessary transformations were performed to obtain the values of the rainfall intensity and the times of concentration for 36 tests which are listed in Table 8.

6.0 REGRESSION ANALYSIS

6.1 Four - Parameter Time of Concentration Equation

A four-parameter equation of the general format of equation (1) was chosen to fit the 375 data points developed in Sections 4.0 and 5.0 for natural and experimental watersheds. This is a volume of data far in excess of those used in the development of any of the equations (2) to (12). In equation (1) the time of concentration is the dependent variable and L, n, S and i are the independent variables. This equation exhibits a linear correlation of the logarithms of the variables involved.

A regression analysis was performed for each group of available data. A power model was used to regress the time of concentration on four predictor variables: length of flow path L, roughness coefficient n, slope of flow path S, and intensity of excess rainfall i. Only two predictor variables were used for the Colorado State University data because L and S were constant throughout the measurements, and similarly for the University of Illinois data where L and n were constant. Table 9 summarizes the results of the regression analysis for each data group and for the total data sample. The table includes estimates of the parameters k, a, b, y and z. The standard deviation of a sample of observations, σ, for log T_c, is also listed in Table 9 together with the coefficient of variation which is the ratio of the standard deviation to the mean, $\sigma/\overline{\log T_c}$. The coefficient of determination is equal to the square of the correlation coefficient R and indicates the percentage of the variation in the variable that is explained by the regression equation. The value of R^2 is always in the range from zero to 1.0 with a value of zero indicating that the variable is not related to any of the predictor variables. The coefficient of determination is also included in Table 9.

Based on the total data sample available, the best-fit four-parameter time of concentration equation was found to be:

$$T_c = 0.66\, L^{0.50}\, n^{0.52}\, S^{-0.31}\, i^{-0.38} \qquad (14)$$

min ft ft/ft in/hr

Values of T_c computed by Equation 14 versus those measured are plotted in Figure 10 using logarithmic scales. Tolerance limits containing 75, 90 and 95% of the sample points are also enveloped in Figure 10.

Statistical tolerance limits for a given population are limits within which a stated proportion of the population are expected to lie with respect to some measurable characteristic. Whereas a confidence interval provides a measure of the accuracy of a statistic (e.g. a mean or regression coefficient), tolerance limits provide bounds on the extend of the population. That is, confidence intervals deal with population statistics, and tolerance limits deal with proportions of a population.

The width of the two-sided tolerance limits is

$$\Delta \log Tc = \pm D\sigma \qquad (15)$$

where σ is the standard deviation computed from a sample of m observations. The factor D is such that the probability is γ that a proportion P(%) of the m observations will be included between the tolerance limits. The factor D is a function of γ, P and m and can be obtained from statistical tables.

The probability γ is called the level of confidence and is equal to (1- α) where α is the level of significance. There is a α% risk of error, for even if the null hypothesis does hold, there is a α% probability that it will be rejected. The value of α is often based on convention and the availability of statistical tables. A value of $\alpha = 0.05$ is being selected frequently. The tolerance interval encloses P percent of the population with a given confidence γ.

For a level of confidence equal to $\gamma = 0.95$ and a sample size of m = 375, values of D for three selected values of P are listed in Table 11 together with the corresponding tolerance limits of the dependent variable T_c. These limits can be transformed to a tolerance interval of the constant k of Equation 1 as shown in Table 11. It is of interest to note that as P increases from 75% to 95%, given the same level of confidence and sample size, the width of the two-sided tolerance limits also increases.

6.2 One Parameter Time of Concentration Equation

The exponents of L and n are almost identical in Equation 14. Furthermore the exponents of i and S are also nearly equal. Therefore, Equation 14 was simplified by combining the four independent parameters in one by adopting the form:

$$T_c = k\,[\mathrm{Ln}\,(Si)^{-2/3}]^x \qquad (16)$$

A linear regression analysis was performed for each group of available data and for the total data sample. Table 10 summarizes the results of the regression including the parameters k and x, the standard deviation of the sample, the coefficient of variation and the coefficient of determination.

Based on the total data sample available, the best-fit one-parameter time of concentration equation was found to be:

$$T_c = 0.52\,[\mathrm{Ln}\,(Si)^{-2/3}]^{0.52} \qquad (17)$$

Observed values of T_c versus those computed by Equation 17 are plotted in Figure 11 using logarithmic scales. Tolerance limits containing 75, 90 and 95% of the sample are enveloped in Figure 11.

For a level of confidence equal to $\gamma = 0.95$ and a sample size of $m = 375$, values of D for three selected values of P are listed in Table 11 together with the corresponding tolerance limits of the dependent variable T_c. These limits can be transformed to a tolerance interval of the constant k of Equation 16 as shown in Table 11.

7.0 UNCERTAINTY ANALYSIS

The uncertainty in the calculated times of concentration T_c can be estimated on the basis of the uncertainties in the measurements of L, n, S and i. Let u_T be the uncertainty in the result and u_L, u_n, u_S, and u_i be the uncertainties in the independent variables. If the uncertainties in the independent variables are all given with the same odds, then the uncertainty in the time of concentration having these odds, is:

$$u_T = \sqrt{\left(\frac{\partial T_c}{\partial L} u_L\right)^2 + \left(\frac{\partial T_c}{\partial n} u_n\right)^2 + \left(\frac{\partial T_c}{\partial S} u_S\right)^2 + \left(\frac{\partial T_c}{\partial i} u_i\right)^2} \quad \text{, or}$$

$$\frac{u_T}{T_c} = \sqrt{\left(0.5 \frac{u_L}{L}\right)^2 + \left(0.52 \frac{u_n}{n}\right)^2 + \left(0.31 \frac{u_S}{S}\right)^2 + \left(0.38 \frac{u_i}{i}\right)^2} \qquad (18)$$

The degree of accuracy with which the independent variables can be measured depends on the observer. However, the following uncertainties can be reasonably expected even from experienced observers:

$u_L/L = \pm 5\%$, $\quad u_S/S = \pm 7\%$

$u_n/n = \pm 25\%$, $\quad u_i/i = \pm 20\%$

Then, Equation 18 yields $u_T/T_c = \pm 15\%$. The uncertainty propagation in the time of concentration predicted by Equation 18 depends on the squares of the uncertainties of the independent variables. This means that if the uncertainty in one variable is significantly larger than the uncertainties in the other variables, then it is the largest uncertainty that predominates and the others may probably be neglected. To illustrate, suppose that $u_n/n = \pm 25\%$ and the other three uncertainties are zero. Equation 18 would then yield $u_T/T_c = \pm 13\%$, fairly close to $\pm 15\%$, the value computed taking into account all four uncertainties.

8.0 DIMENSIONS AND UNITS

The roughness coefficient, n, was considered to be dimensionless in Equation 1. Then the constant k has the following dimensions:

$$[k] = [T]\,[L]^{-a}\,[i]^{z}$$

English customary units for Equation 1 are the minute as unit of time, the foot as unit of length, and the inch per hour as unit of rainfall intensity. Table 12 summarizes the conversion factors by which k should be multiplied to convert the English customary units to the International System (SI) and to the Metric customary units where meter is the unit of length and the centimeter per hour is the unit of rainfall intensity.

9.0 CONCLUSIONS AND RECOMMENDATIONS

A comparison was performed between the four-parameter time of concentration equation 14 and the equations presented in Section 2.0. The comparison was based on the exponents of the independent variables L, S and i which are listed in Table 13. These exponents were chosen for comparison rather than the numerical values of the time of concentration to avoid the selection of retardance coefficients, the definition of which varies from equation to equation.

From Table 12 the following conclusions can be made:

a) The exponents of L in the equations of Carter, Kinematic Wave, Morgali, FAA and Kerby agree within $\pm 20\%$ with the exponent a of Equation 14.
b) The exponents of S in the equations of Izzard, FAA, Kerby, Carter, Kinematic Wave, Morgali and Singh agree within $\pm 25\%$ with the exponent y of Equation 14.
c) The exponents of i in the equations of Kinematic Wave, Morgali and Singh agree within $\pm 15\%$ with the exponent z of Equation 14.

The three case studies of Section 3.0 were also used to compare the time of concentration computed from Equation 14 with the values obtained from the other eleven equations and those measured (see Table 1). The spread in these values is depicted in Figure 12. Results from Equation 14 closely agree with the measured times of concentration. The 75% tolerance limits are also marked on Figure 12 to show that almost the only other equation that showed good agreement with the measurements is the Kinematic Wave equation. The derived four-parameter Equation 14 has more general applicability compared to the Kinematic Wave equation which is more appropriate for computing the time of concentration of very small rural watersheds where surface flow is predominant.

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TABLE 1
TIMES OF CONCENTRATION FOR THREE CASE STUDIES

Formula	Hastings, Nebraska 3.62 acres-Case Study I Retardance Coefficient	T_c(min)	Americus, Georgia 59.2 acres-Case Study II Retardance Coefficient	T_c(min)	Hamilton, Ohio 187 acres-Case Study III Retardance Coefficient	T_c(min)
a) Kirpich	---	2.5	---	36	---	29
b) Izzard	$C_i = 0.03$	16.3	$C_i = 0.03$	120	$C_i = 0.03$	33
c) Kerby	$n_k = 0.35$	16.5	$n_k = 0.30$	79	$n_k = 0.2$	57
d) Carter	$C_c = 0.045$	3.8	$C_c = 0.045$	32	$C_c = 0.045$	27
e) Eagleson	$C_e = 0.107$	14.7	$C_e = 0.052$	56	$C_e = 0.052$	59
f) Kinematic Wave	n = 0.05	11.1	n = 0.04	97	n = 0.035	40
g) Morgali	n = 0.05	13.7	n = 0.04	149	n = 0.035	57
h) FAA	C = 0.30	16.2	C = 0.3	119	C = 0.30	94
i) SCS Curve Number	CN = 70	8.6	CN = 85	175	CN = 90	71
j) SCS Velocity	$C_v = 0.30$	8.8	$C_v = 0.14$	133	$C_v = 0.12$	87
K) Singh/Chezy	$C_s = 20$	9.6	$C_s = 25$	117	C = 29	45
l) Measured	---	10.8	---	67	---	27

TABLE 2

84 NATURAL RURAL WATERSHEDS IN 22 STATES USDA AGRICULTURAL RESEARCH SERVICE [1]

State	Number of Watersheds
Arkansas	2
California	2
Colorado	2
Georgia	1
Idaho	3
Illinois	2
Indiana	3
Iowa	5
Maryland	5
Mississippi	2
Missouri	2
Nebraska	9
New Jersey	2
New Mexico	3
Ohio	7
Oklahoma	9
Oregon	3
Texas	9
Virginia	5
Washington	1
West Virginia	3
Wisconsin	4

TABLE 3

PHYSICAL AND HYDROLOGICAL CHARACTERISTICS OF THE SELECTED NATURAL WATERSHEDS
USDA - AGRICULTURAL RESEARCH SERVICE [1]

		Physical Characterisitics of Watershed				Excess Rainfall							
No.	Watershed Site,State(#)	Area A Acres	Length L Feet	Roughness (estimated) n	Slope S Feet/Foot	Date Month/ Day/Year	Vol. V Inches	Duration T_r min.	Intensity i inch/hr.	Time of Equi-Librium T_e min.	Time to Peak T_p min.	Lag Time T_e min.	Time of Concen tration T_c min.
1	Bentonville, AR(W5)	19.4	1290	0.16	0.017	5/25/39	0.424	24	1.06	22.0			22.0
2.	Bentonville,AR(W5)	19.4	1290	0.16	0.017	8/31/40	0.227	5	2.72		22.0	19.5	32.5
3.	Watsonville, CA(W3)	27.4	1660	0.16	0.108	2/16/41	0.035	8	0.26		29.0	25.0	41.7
4.	Watsonville,CA(W3)	27.4	1660	0.16	0.108	4/1/41	0.121	25	0.29		41.0	28.5	47.5
5.	Col. Springs, CO(W4)	35.6	2460	0.10	0.039	8/13/45	0.383	6	3.82		15.0	12.0	20.0
6.	Col.Springs, CO(W4)	35.6	2460	0.10	0.039	7/15/46	0.194	10	1.16		18.0	13.0	21.7
7.	Americus,GA(W4)	59.2	3380	0.14	0.0035	8/19/42	0.168	10.	1.01		45.0	40.0	66.7
8.	EMMETT,ID(W2)	69.4	2680	0.10	0.160	6/18/41	0.022	4	0.33		16.0	14.0	23.3
9.	Emmett,ID(W2)	69.4	2680	0.10	0.160	6/19/41	0.020	5	0:24		18.5	16.0	26.7
10.	Moscow,ID(W1)	146.8	4040	0.10	0.047	4/9/41	0.006	5	0.067		70.0	67.5	112.5
11.	Monticello,IL(W1A)	82.0	2540	0.10	0.008	10/21/49	0.212	6	2.12		40.0	37.0	61.7
12.	Monticello,IL(W1A)	61.2	2650	0.13	0.0053	10/21/49	0.255	5	3.06		30.0	27.5	45.8
13.	Lafayette,IN(W5)	2.87	470	0.15	0.017	7/5/43	0.320	9	2.13		10.0	5.5	9.2

No.		A	L	n	S	Date	V	T_r	i	T_e	T_p	T_e	T_c
14	Lafayette, IN(W5)	2.9	470	0.15	0.017	6/19/46	0.360	12	1.80		15.0	9.0	15.0
15	Lafayette, IN(W6)	2.8	580	0.14	0.017	6/24/50	0.920	9	6.13		10.0	5.5	9.2
16	Treynor, IA(W1)	74.5	3100	0.06	0.029	6/22/64	0.571	16	2.14		19.0	11.0	18.3
17	Treynor, IA(W2)	82.4	3000	0.05	0.025	9/22/64	0.295	9	1.97		12.0	7.5	12.5
18	Treynor, IA(W3)	107.0	2930	0.08	0.038	5/26/64	0.108	13	0.50		23.0	16.5	27.5
19	Treynor, IA(W4)	150.0	4000	0.08	0.025	6/22/64	0.223	13	1.06		19.5	13.0	21.7
20	Treynor,IA(W5)	389.0	7800	0.07	0.022	6/22/64	0.147	12	0.79		30.0	24.0	40.0
21	Coll. Park,MD(W1)	8.2	1320	0.18	0.025	8/3/48	1.017	18	4.40	15.0			15.0
22	Coll. Park, MD(W6)	3.5	720	0.24	0.040	8/27/43	0.241	6	2.41		12.0	9.0	15.0
23	Coll. Park, MD(W7)	4.1	810	0.23	0.040	8/27/43	0.549	4	1.44		13.0	11.0	18.3
24	Coll. Park,MD(W9)	12.1	1290	0.26	0.053	11/25/50	0.298	34	0.53		62.0	45.0	75.0
25	Hagerstown, MD(W2)	80.8	3120	0.10	0.045	7/20/42	0.180	15	0.72		25.0	17.5	29.2
26	Oxford, MS(WC1)	3.9	480	0.25	0.062	6/11/59	1.360	22	3.65		21.0	10.0	16.7
27	Oxford, MS(WP4)	3.0	470	0.25	0.068	6/11/59	1.510	22	4.12		18.5	7.5	12.5
28	Bethany, MO(WD3)	4.5	680	0.16	0.062	5/1/35	0.790	23	2.06	13.0			13.0
29	Bethany, MO(WD3)	4.5	680	0.16	0.062	6/17/35	0.560	20	1.68	12.0			12.0
30	Hastings, NE(W3)	481.0	12250	0.05	0.0057	6/7/53	0.879	44	1.20		56.0	34.0	56.7

No.		A	L	n	S	Date	V	T_r	i	T_e	T_p	T_e	T_c
31	Hastings,NE(W5)	411.0	7500	0.09	0.011	7/3/59	1.358	44	1.85		65.0	43.0	71.7
32	Hastings,NE(W1H)	3.6	480	0.15	0.075	6/16/57	0.340	12	1.70		12.5	6.5	10.8
33	Hastings,NE(W2H)	3.4	610	0.17	0.047	6/12/58	0.180	7	1.54		15.0	11.5	19.2
34	Hastings,NE(W5H)	3.9	670	0.13	0.052	5/4/59	0.130	10	0.78	9.0			9.0
35	Hastings,NE(W7H)	4.3	670	0.13	0.034	5/4/59	0.140	6	1.40		8.0	5.0	8.3
36	Hastings,NE(W18H)	3.5	510	0.17	0.055	5/18/59	0.190	10	1.14		18.0	13.0	21.7
37	Hastings,NE(W22H)	3.8	500	0.14	0.026	8/23/62	1.100	19	3.47		18.5	9.0	15.0
38	Hastings,NE(W23H)	4.2	610	0.14	0.036	8/23/62	1.120	19	3.54		20.0	10.5	17.5
39	Freehold,NJ(W1)	15.7	1890	0.09	0.018	6/12/38	0.242	5	2.90		14.0	11.5	19.2
40	Freehold,NJ(W2)	32.9	1740	0.09	0.026	8/6/38	0.436	20	1.31	17.0			17.0
41	Santa Fe,NM(W1)	141.0	2910	0.05	0.019	8/25/47	0.381	9	2.54		17.0	12.5	20.8
42	Santa Fe,NM(W1)	141.0	2910	0.05	0.019	8/4/48	0.171	16	0.64		27.0	19.0	31.7
43	Santa Fe,NM(W3)	183.0	5170	0.05	0.033	8/19/56	0.191	11	1.04		16.0	10.5	17.5
44	Hamilton,OH(W1)	187.0	5000	0.09	0.013	5/17/43	0.495	6	4.95		19.0	16.0	26.7
45	Cochocton,OH(W183)	74.2	3140	0.11	0.071	8/16/47	0.195	12	0.98		21.0	15.0	25.0
46	Cochocton,OH(W196)	303.0	4570	0.10	0.055	8/16/47	0.249	9	1.66		27.0	22.5	37.5
47	Cochocton,OH (W166)	79.2	2910	0.11	0.069	7/7/69	0.362	17	1.28		34.0	25.5	42.5
48	Cochocton,OH(W185)	7.4	560	0.19	0.110	6/12/57	0.700	16	2.63		17.0	9.0	15.0

No.		A	L	n	S	Date	V	T_r	i	T_e	T_p	T_e	T_c
49	Cochocton,OH(W192)	7.6	710	0.18	0.140	6/12/59	0.700	16	2.63		18.0	10.0	16.7
50	Cochocton,OH(W172)	43.6	2430	0.17	0.082	6/12/59	1.372	27	3.05		36.0	22.5	37.5
51	Guthrie,OK(W6)	94.8	3300	0.11	0.024	6/26/45	0.315	10	1.89		25.0	20.0	33.3
52	Stillwater,OK(W3)	92.0	3330	0.13	0.021	6/27/57	0.757	10	4.54		33.0	28.0	46.7
53	Cherokee,OK(W9)	8.5	840	0.16	0.012	6/9/42	0.490	10	2.94		17.0	12.0	20.0
54	Cherokee,OK(W10)	1.7	350	0.20	0.021	6/2/61	1.020	25	2.45		20.0	7.5	12.5
55	Cherokee, OK(W11)	2.1	420	0.19	0.013	6/2/61	0.950	25	2.28		29.0	16.5	27.5
56	Cherokee, OK(W12)	1.7	400	0.21	0.015	6/2/61	1.290	30	2.58	24.0			24.0
57	Cherokee, OK(W14)	2.2	350	0.20	0.011	6/2/61	1.080	35	1.85	25.0			25.0
58	Cherokee, OK(W15)	2.2	430	0.20	0.010	6/2/61	1.120	35	1.92	30.0			30.0
59	Chickasha, OK(WC8)	27.3	2440	0.18	0.018	9/19/65	0.274	32	0.51		60.0	44.0	73.3
60	Newberg, OR(W1)	13.2	1170	0.16	0.142	10/1/41	0.138	10	0.83		14.5	9.5	15.8
61	Newberg, OR(W3)	12.8	800	0.16	0.087	3/31/40	0.076	9	0.51		20.0	15.5	25.8
62	Newberg, OR(W4)	6.2	820	0.19	0.079	1/26/40	0.011	10	0.066		37.5	32.5	54.2
63	Vega, TX(W2)	95.9	4440	0.08	0.018	5/30/38	0.700	13	3.23		21.5	15.0	25.0
64	Riesel(Waco), TX(W1)	176.0	5500	0.10	0.0091	6/10/41	2.024	34	3.57		44.0	27.0	45.0
65	Riesel(Waco), TX(SW12)	3.0	420	0.20	0.029	6/4/57	0.270	13	1.25		23.0	16.5	27.5

No.		A	L	n	S	Date	V	T_r	i	T_e	T_p	T_e	T_c
66	Riesel(Waco), TX(Y13)	11.3	1380	0.19	0.012	5/23/69	0.341	30	0.68		59.0	44.0	73.3
67	Riesel(Waco), TX(SW20)	3.2	500	0.20	0.040	10/23/70	0.080	10	0.45		16.0	11.0	18.3
68	Sonora, TX(W1)	10.2	890	0.20	0.037	4/30/66	1.299	30	2.60	20.0			20.0
69	Sonora, TX(W3)	6.7	820	0.20	0.022	4/30/66	1.259	26	2.91	25.0			25.0
70	Sonora, TX(w4)	4.5	570	0.20	0.019	4/30/66	0.247	15	0.99		27.0	19.5	32.5
71	Sonora, TX(W6)	6.9	710	0.20	0.021	4/30/66	0.911	20	2.73	16.0			16.0
72	Chatham, VA(W3)	17.1	1380	0.16	0.021	8/31/40	0.898	19	2.84		23.0	13.5	22.5
73	Staunton, VA(W1)	390.0	8250	0.08	0.025	4/13/49	0.474	20	1.42		46.0	36.0	60.0
74	Blacksburg, VA(PCW1)	182.0	4830	0.12	0.021	7/22/64	0.230	24	0.58		52.0	40.0	66.7
75	Blacksburg,VA(PMBW1)	192.0	4640	0.15	0.097	6/17/68	0.069	35	0.12		80.0	62.5	104.2
76	Blacksburg, VA(W3)	19.3	1490	0.16	0.047	8/15/39	0.368	16	1.38		22.0	14.0	23.3
77	Pullman, WA(GS2)	68.2	2720	0.11	0.064	3/3/41	0.015	15	0.06		35.0	27.5	45.8
78	Moorefield, WV(W1	8.2	1210	0.17	0.100	8/3/58	0.300	24	0.75		27.0	15.0	25.0
79	Moorefield, WV(W2)	10.1	1010	0.17	0.110	8/3/58	0.522	30	1.04	25.0			25.0
80	Moorefield, WV(W5)	9.5	1180	0.17	0.070	8/3/58	0.540	13	2.26		19.0	12.5	20.8
81	Colby, WI (W1)	345.0	7100	0.07	0.010	5/13/56	0.439	11	2.36		29.0	23.5	39.2
82	Fennimore, WI (W1)	330.0	5300	0.09	0.024	6/28/45	0.483	8	3.63		24.0	20.0	33.3
83	Fennimore, WI (W2)	22.8	1210	0.15	0.063	6/28/45	0.615	6	6.15		8.5	5.5	9.2
84	Fennimore, WI (W4)	171.0	3330	0.10	0.026	6/28/45	0.468	8	3.51		15.0	11.0	18.3

TABLE 4
COMPARISON BETWEEN (n) VALUES PROPOSED BY
V.T. CHOW, MITCAT, AND PENN. STATE U.

Type of Surface	V.T. Chow	MITCAT	Penn. State
Smooth impervious,concrete, asphalt	0.01-0.02	0.05-0.15	0.035
Smooth bare packed soil (no crop)	0.02-0.04		0.05
Poor grass, moderately bare surface	0.025-0.035		0.10
Lawns		0.20-0.30	
Gravel, cobbles	0.03-0.05		
Pasture or average grass cover	0.03-0.05	0.30-0.40	0.20
Mature field crops	0.03-0.05		
Light brush and trees	0.04-0.08		
Dense brush	0.07-0.16		
Dense grass or forest (dense willows)	0.11-0.20	0.40-0.50	0.40

TABLE 5

SIMULATED RAINFALL TESTS - CORPS OF ENGINEERS [2]
CONCRETE SURFACE WITH n = 0.04

Slope of the Trough

Length L (ft)	S = 0.005 Rain Rate i (in/hr)	S = 0.005 Average T_e (min)	S = 0.010 Rain Rate i (in/hr)	S = 0.010 Average T_e (min)	S = 0.020 Rain Rate i (in/hr)	S = 0.020 Average T_e (min)
84	--	--	0.44	8.26	0.62	5.30
84	0.86	8.92	1.04	5.41	1.03	3.60
84	1.75	5.82	2.02	3.60	2.12	3.11
84	3.82	4.64	3.81	2.83	4.11	2.16
84	6.55	3.25	7.35	2.15	7.34	1.75
168	0.90	11.09	0.58	9.49	0.57	7.04
168	1.68	8.22	1.00	6.55	1.07	4.98
168	3.85	5.65	1.93	5.15	2.04	3.96
168	6.95	4.21	4.19	3.79	4.11	3.28
168	8.26	3.77	7.52	3.01	7.46	2.39
252	0.91	12.50	0.45	12.54	0.62	8.12
252	1.79	8.94	1.02	7.95	1.04	6.42
252	3.84	6.50	1.74	6.33	2.01	4.88
252	6.79	5.02	4.14	4.44	4.08	3.66
252	8.40	4.07	7.47	3.54	7.31	2.86
336	0.89	13.53	0.52	12.66	0.63	9.15
336	1.76	10.38	0.90	9.80	1.01	7.55
336	3.75	6.95	2.02	6.88	2.03	5.68
336	6.50	5.65	4.17	5.22	4.06	4.34
336	8.31	4.97	7.61	4.14	7.43	3.34
420	0.89	14.94	0.63	12.08	0.56	11.12
420	1.77	11.05	1.04	10.60	1.01	8.39
420	3.85	8.02	2.03	7.67	2.02	6.42
420	6.57	6.22	4.19	5.80	3.99	4.82
420	8.24	5.49	7.63	4.54	7.43	3.72
500	0.85	16.33	0.61	13.98	0.58	11.83
500	1.79	11.89	0.92	11.73	0.98	9.16
500	3.71	8.72	2.00	8.64	2.05	7.04
500	6.61	6.59	4.02	6.31	3.99	5.21
500	7.94	5.86	7.49	4.95	7.44	4.22

TABLE 6

SIMULATED RAINFALL TESTS - CORPS OF ENGINEERS [2]
SIMULATED TURF WITH n = 0.20

Slope of the Trough

Length L (ft)	S = 0.005 Rain Rate i (in/hr)	S = 0.005 Average T_e (min)	S = 0.010 Rain Rate i (in/hr)	S = 0.010 Average T_e (min)	S = 0.020 Rain Rate i (in/hr)	S = 0.020 Average T_e (min)
84	0.61	24.00	0.61	16.66	0.63	12.09
84	1.04	16.84	0.99	13.24	1.03	10.07
84	2.00	11.20	1.98	9.03	2.02	7.91
84	3.94	7.78	3.82	5.89	4.06	5.36
84	7.45	5.28	8.13	4.05	7.40	4.00
168	1.02	21.25	1.01	16.94	1.02	15.27
168	2.03	14.31	1.88	11.50	1.97	10.76
168	3.89	9.84	4.08	7.82	4.04	7.04
252	1.04	24.50	0.99	19.92	1.05	17.52
252	2.00	16.61	1.95	13.57	1.92	12.40
252	3.98	11.57	3.98	9.95	4.08	8.45
336	0.60	36.67	0.57	30.54	0.60	26.87
336	1.05	27.14	0.99	21.74	1.03	19.66
336	2.01	18.59	2.00	15.37	1.97	13.99
336	3.95	12.92	4.05	10.93	3.92	9.59
336	7.53	9.25	7.50	7.56	7.61	6.56
420	0.62	38.37	--	--	--	--
420	1.03	29.18	0.96	23.88	1.04	21.40
420	2.02	20.14	2.04	17.62	1.92	15.20
420	3.99	14.16	3.83	12.29	3.93	10.37
500	0.61	41.51	0.60	33.06	0.65	29.19
500	1.00	31.82	1.00	25.91	1.01	23.82
500	2.00	22.02	2.03	18.93	1.94	16.85
500	3.93	15.29	3.92	13.17	3.96	10.80
500	7.45	10.94	7.50	8.78	7.46	7.78

TABLE 7

TIMES OF CONCENTRATION FOR THE COLORADO STATE UNIVERSITY EXPERIMENTS

No.	Run #	Date	Rainfall Intensity i inch/hr	Rainfall Duration T_r min	Time of Equilibrium T_e min	Time to Peak T_p min	Lag Time T_l min	Time of Concentr. T_c min
	Configuration No. 9 (1970): L = 110 ft., S = 0.05, n = 0.13							
1	71B	8/7	0.440	1.25		5.22	4.60	7.66
2	72	8/7	0.859	10.63	6.83			6.83
3	73	8/7	1.922	9.87	5.33			5.33
4	74A	8/10	4.228	9.87	3.73			3.73
5	74B	8/10	4.250	9.85	3.67			3.67
6	75A	8/10	2.019	10.37	4.45			4.45
7	75B	8/10	2.017	10.22	5.10			5.10
8	77B	8/10	0.440	1.36		4.67	3.99	6.65
9	78B	8/11	0.440	2.01		4.80	3.80	6.33
10	79B	8/11	0.440	2.83		4.97	3.56	5.93
11	80B	8/11	0.440	3.40		5.45	3.75	6.25
12	84	8/11	0.859	1.01		4.00	3.50	5.83
13	85	8/11	0.859	1.88		4.05	3.11	5.18
14	86	8/11	0.859	3.03		4.67	3.16	5.26
15	88B	8/11	2.019	1.09		3.52	2.98	4.96
16	89	8/11	2.019	1.74		3.50	2.63	4.38
17	90	8/11	2.019	2.21		3.55	2.45	4.08
18	91	8/11	2.019	2.38		3.43	2.24	3.73
19	94	8/12	4.228	1.14		2.42	2.35	3.92
20	96	8/12	4.228	1.29		2.93	2.29	3.81
	Configuration No. 14 (1970): L = 110 ft., S = 0.05, n = 0.16							
21	144	8/24	0.427	7.32	6.13			6.13
22	145	8/24	0.935	8.50	6.12			6.12
23	146A	8/24	1.839	8.00	5.13			5.13
24	147	8/24	2.838	9.05	4.75			4.75
25	148	8/24	3.559	8.10	4.45			4.45
26	149	8/27	0.784	4.54		5.67	3.40	5.67
27	150	8/27	0.784	1.03		4.63	4.12	6.86
28	151	8/27	1.802	3.79		4.83	2.94	4.89
29	153	8/27	2.838	3.25		3.88	2.26	3.76
30	155	8/27	3.675	3.41		3.77	2.07	3.44
31	159	8/28	0.784	8.35	6.53			6.53
32	160	8/28	1.805	7.70	4.85			4.85
33	161	8/28	2.610	16.85	4.62			4.62
34	162A	8/28	3.675	6.77	4.37			4.37

Table 7 (Cont.)

No.	Run	Date	Rainfall Intensity i inch/hr	Rainfall Duration T_r min	Time of Equilibrium T_e min	Time to Peak T_p min	Lag Time T_l min	Time of Concentr. T_c min
	Configuration No. 20 (1970): L = 110 ft., S = 0.05, n = 0.20							
35	162B	9/1	0.390	11.05	8.05			8.05
36	163	9/1	0.837	9.15	6.48			6.48
37	164	9/1	1.799	9.52	5.68			5.68
38	165	9/1	2.619	8.90	5.23			5.23
39	166	9/1	3.769	8.32	4.98			4.98
40	169	9/2	0.837	4.30		6.40	4.25	7.08
41	170	9/2	1.799	1.13		5.58	5.02	8.36
42	171	9/2	1.799	4.24		6.03	3.91	6.52
43	173A	9/2	3.769	3.50		4.17	2.42	4.03
44	175A	9/2	2.619	4.18		4.87	2.78	4.63
	Configuration No. 21 (1970): L = 110 ft., S = 0.05, n = 0.25							
45	177A	9/4	0.391	13.25	10.97			10.97
46	178A	9/4	0.842	10.38	10.27			10.27
47	179A	9/4	1.760	10.75	6.97			6.97
48	180A	9/4	2.617	8.63	6.00			6.00
49	181A	9/4	3.552	8.70	5.03			5.03
	Configurations No. 22, 23, 24 (1970): L = 110 ft., S = 0.05, n = 0.035							
50	182B	9/16	1.791	2.08		7.67	6.63	11.05
51	183	9/16	1.791	3.42		7.75	6.04	11.07
52	184	9/16	1.791	5.58		6.67	3.88	6.47
53	186	9/17	3.709	1.42		6.00	5.29	8.82
54	187	9/17	3.709	1.79		5.83	4.94	8.23
55	188	9/17	3.709	2.62		4.82	3.51	5.85
56	190	9/22	0.895	9.85	8.83			8.83
57	191	9/22	0.890	1.10		7.50	6.95	11.58
58	192	9/22	0.890	3.79		6.20	4.31	7.18
59	193	9/22	0.890	5.74		6.67	3.80	6.33
60	194	9/22	4.025	12.65	5.72			5.72
61	196	9/22	4.025	2.07		3.33	2.30	3.83
62	197	9/22	4.025	3.50		4.00	2.25	3.75
63	198	9/24	0.877	10.73	8.47			8.47
64	199	9/24	0.877	1.35		5.77	5.10	8.49
65	200	9/24	0.877	3.72		4.88	3.02	5.03
66	203	9/25	3.368	9.30	5.80			5.80
67	204	9/25	3.734	6.80	5.47			5.47
68	207	9/25	3.734	2.25		3.12	2.00	3.33

Table 7 (Cont.)

No.	Run	Date	Rainfall Intensity i inch/hr	Rainfall Duration T_r min	Time of Equilibrium T_e min	Time to Peak T_p min	Lag Time T_l min	Time of Concentr. T_c min
	Configuration No. 17 (1970): L = 100 ft., S = 0.05, n = 0.035							
69	113B	8/14	0.871	11.63	4.23			4.23
70	114	8/14	1.821	9.83	2.77			2.77
71	115	8/14	3.610	9.85	2.25			2.25
72	118	8/18	0.871	1.70		2.50	1.65	2.75
73	120	8/18	1.821	1.47		1.87	1.14	1.89
74	121	8/18	1.821	1.99		2.33	1.34	2.23
75	123	8/18	3.756	2.30	1.75			1.75
76	125	8/19	0.740	9.55	4.80			4.80
77	126	8/19	0.816	6.88	4.05			4.05
78	127	8/19	1.850	4.93	2.77			2.77
79	128	8/19	3.756	3.97	1.90			1.90
80	129	8/20	0.437	8.95	6.80			6.80
	Configuration No. 27 (1971): L = 186 ft, S = 0.0425, n = 0.035							
81	306	7/28	0.997	5.93	4.45			4.45
82	307	7/28	0.413	7.10	5.77			5.77
83	308	7/28	2.097	4.95	3.05			3.05
84	309	7/28	4.086	3.03	2.22			2.22
85	312	7/28	4.234	1.06		1.75	1.22	2.03
86	313	7/28	4.234	1.48		1.92	1.18	1.97
87	314	7/28	4.270	4.02	2.04			2.04
88	316	7/28	2.097	1.94		2.50	1.53	2.55
89	317	7/28	2.097	2.90		3.13	1.68	2.80
90	319	7/29	0.977	1.89		3.27	2.33	3.88
91	320	7/29	0.977	3.10		3.83	2.28	3.80
92	322	7/30	0.413	1.67		4.37	3.54	5.89
93	323	7/30	0.413	2.38		4.55	3.36	5.60

TABLE 8
TIMES OF CONCENTRATION FOR THE UNIVERSITY OF ILLINOIS EXPERIMENTAL WATERSHED TESTS

Fig. in Ref. [17]	No.	Average Slope S ft/ft	Rainfall Intensity i inch/hr	Rainfall Duration T_r min	Time of Equilibrium T_e min	Time to Peak T_p min	Lag Time T_l min	Time of Concen. T_c min
A1.a	1	0.067	2.72	1.22		3.27	2.66	4.43
A1.a	2	0.067	2.72	2.44		3.78	2.56	4.27
A1.a	3	0.067	2.72	9.84	5.03			5.03
A1.b	4	0.067	4.29	1.23		3.05	2.44	4.06
A1.b	5	0.067	4.29	2.45		3.68	2.46	4.09
A1.b	6	0.067	4.29	9.84	4.64			4.64
A1.c	7	0.067	4.83	1.22		3.09	2.48	4.13
A1.c	8	0.067	4.83	2.54		3.84	2.57	4.28
A1.c	9	0.067	4.83	9.75	4.91			4.91
A1.d	10	0.067	6.86	1.23		2.80	2.19	3.64
A1.d	11	0.067	6.86	2.44		3.10	1.88	3.13
A1.d	12	0.067	6.86	4.93	3.85			3.85
A2.a	13	0.010	2.73	1.22		2.77	2.16	3.60
A2.a	14	0.010	2.73	2.45		3.26	2.04	3.39
A2.a	15	0.010	2.73	9.95	4.14			4.14
A2.b	16	0.010	4.34	1.23		2.61	2.00	3.33
A2.b	17	0.010	4.34	2.46		3.32	2.09	3.48
A2.b	18	0.010	4.34	9.93	3.71			3.71
A2.c	19	0.010	4.82	1.23		2.50	1.89	3.14
A2.c	20	0.010	4.82	2.46		3.20	1.97	3.28
A2.c	21	0.010	4.82	9.80	3.42			3.42
A2.d	22	0.010	6.88	1.21		2.24	1.64	2.73
A2.d	23	0.010	6.88	2.49		2.89	1.65	2.74
A2.d	24	0.010	6.88	4.92	3.14			3.14
A3.a	25	0.023	2.75	1.23		2.37	1.76	2.93
A3.a	26	0.023	2.75	2.43		2.98	1.77	2.94
A3.a	27	0.023	2.75	9.87	3.49			3.49
A3.b	28	0.023	4.32	1.23		2.06	1.45	2.41
A3.b	29	0.023	4.32	2.46		2.78	1.55	2.58
A3.b	30	0.023	4.32	9.84	3.03			3.03
A3.c	31	0.023	4.82	1.22		2.14	1.53	2.55
A3.c	32	0.023	4.82	2.44		2.85	1.68	2.72
A3.c	33	0.023	4.82	4.92	3.13			3.13
A3.d	34	0.023	6.84	1.21		2.05	1.45	2.41
A3.d	35	0.023	6.84	2.47		2.76	1.53	2.54
A3.d	36	0.023	6.84	4.95	3.01			3.01

TABLE 9
FOUR-PARAMETER T_c EQUATION*
REGRESSION ANALYSIS RESULTS

Data Source & Watershed Type	No.of Data	k	a	b	y	z	Standard Deviation σ	Coeff. of Variation $\sigma/\overline{\log T_c}$ (%)	R^2 (%)
USDA-ARS Natural	84	1.04	0.60	0.96	0.24	0.29	0.126	9.0	76.8
US Corps Experimental	162	0.95	0.41	0.49	0.33	0.47	0.035	3.7	98.6
CSU Eperimental	93			0.43		0.30	0.089	12.4	75.2
Univ. of Illinois Experimental	36				0.30	0.24	0.044	8.4	76.4
All Experimental Corps + CSU + UI	291	0.75	0.42	0.48	0.26	0.42	0.062	7.7	95.5
All data Natural plus Experimental	375	0.66	0.50	0.52	0.31	0.38	0.092	9.8	94.1

* Equation $T_c = k\, L^a\, n^b\, S^{-y}\, i^{-z}$

TABLE 10

ONE-PARAMETER T_c EQUATION* REGRESSION ANALYSIS RESULTS

Data Source & Watershed Type	No. of Data	k	x	Standard Deviation σ	Coef. of Variation $\sigma/\overline{\log T_c}$ (%)	R^2 (%)
USDA-ARS Natural	84	0.98	0.44	0.140	10.0	70.5
UC Corps Experimental	162	0.49	0.52	0.070	6.8	95.1
CSU Experimental	93	0.62	0.47	0.090	12.6	79.3
Univ. of Illinois Experimental	36	0.75	0.43	0.040	8.4	75.6
All Experimental Corps + CSU + UI	291	0.55	0.50	0.070	8.8	94.1
All data Natural plus Experimental	375	0.52	0.52	0.095	10.0	93.7

* Equation $T_c = k\,[L\,n\,(Si)^{-2/3}]^x$

Table 11
TOLERANCE LIMITS

	P(%)	D	$\Delta\overline{\log T_c}$	Tolerance Interval of T_c	Best Fit k	Tolerance Interval of k
Four Parameter	75	1.23	± 0.113	$0.77 < T_c/\overline{T}_c < 1.30$		$0.51 < k < 0.86$
Equation 14	90	1.75	± 0.161	$0.69 < T_c/\overline{T}_c < 1.45$	0.66	$0.45 < k < 0.96$
	95	2.09	± 0.192	$0.64 < T_c/\overline{T}c < 1.56$		$0.42 < k < 1.03$
One Parameter	75	1.23	± 0.117	$0.76 < T_c/\overline{T}_c < 1.31$		$0.40 < k < 0.68$
Equation 17	90	1.75	± 0.166	$0.68 < T_c/\overline{T}_c < 1.47$	0.52	$0.35 < k < 0.76$
	95	2.09	± 0.199	$0.63 < T_c/\overline{T}_c < 1.58$		$0.33 < k < 0.82$

TABLE 12
UNITS OF THE TIME OF CONCENTRATION EQUATION

Units	T	L	i	k of Four-Parameter Equation 14	k of One-Parameter Equation 17
English Customary	min	ft	in/hr	k	k
International System (SI)	sec	m	m/sec	1.18k	1.86k
Metric Customary	min	m	cm/hr	2.60k	2.55k

TABLE 13

COMPARISON OF EXPONENTS BETWEEN VARIOUS TIME OF CONCENTRATION EQUATIONS

Equation	Exponent of L	Exponent of S	Exponent of i
a) Kirpich	0.77	−0.385	0
b) Izzard	0.33	−0.333	−0.667
c) Kerby	0.467	−0.233	0
d) Carter	0.60	−0.30	0
e) Eagleson	0.76	−0.19	0
f) Kinematic Wave	0.60	−0.30	−0.40
g) Morgali	0.593	−0.38	−0.388
h) FAA	0.50	−0.333	0
i) SCS Curve	0.80	−0.50	0
j) SCS Velocity Method	1.0	−0.50	0
k) Singh/Chezy	0.667	−0.333	−0.333
l) 4-parameter Equation 14	0.50	−0.31	−0.38
m) 1-parameter Equation 17	0.52	−0.35	−0.35

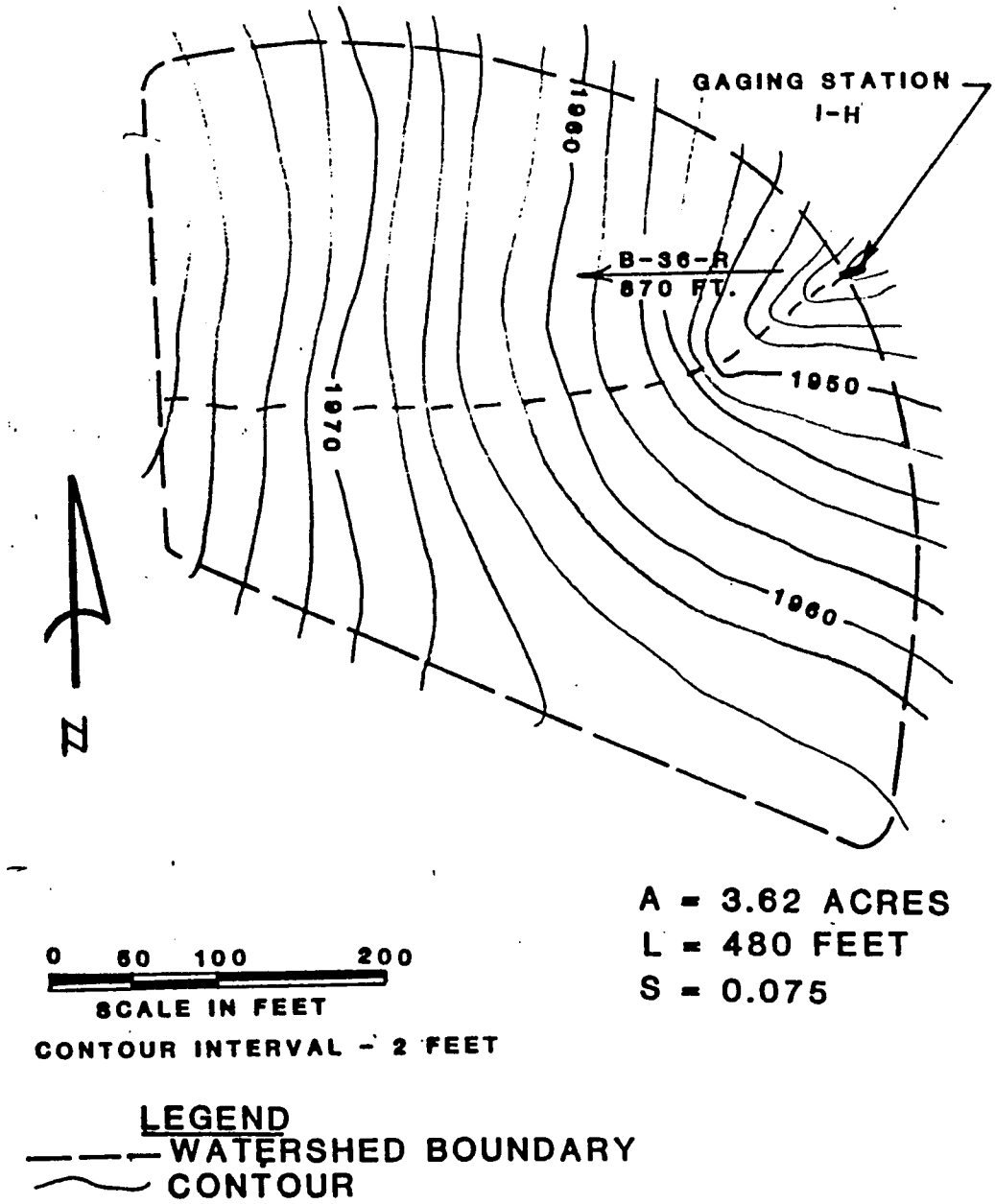


Figure 1. WATERSHED 1-H IN HASTINGS, NEBRASKA. PLAN VIEW.

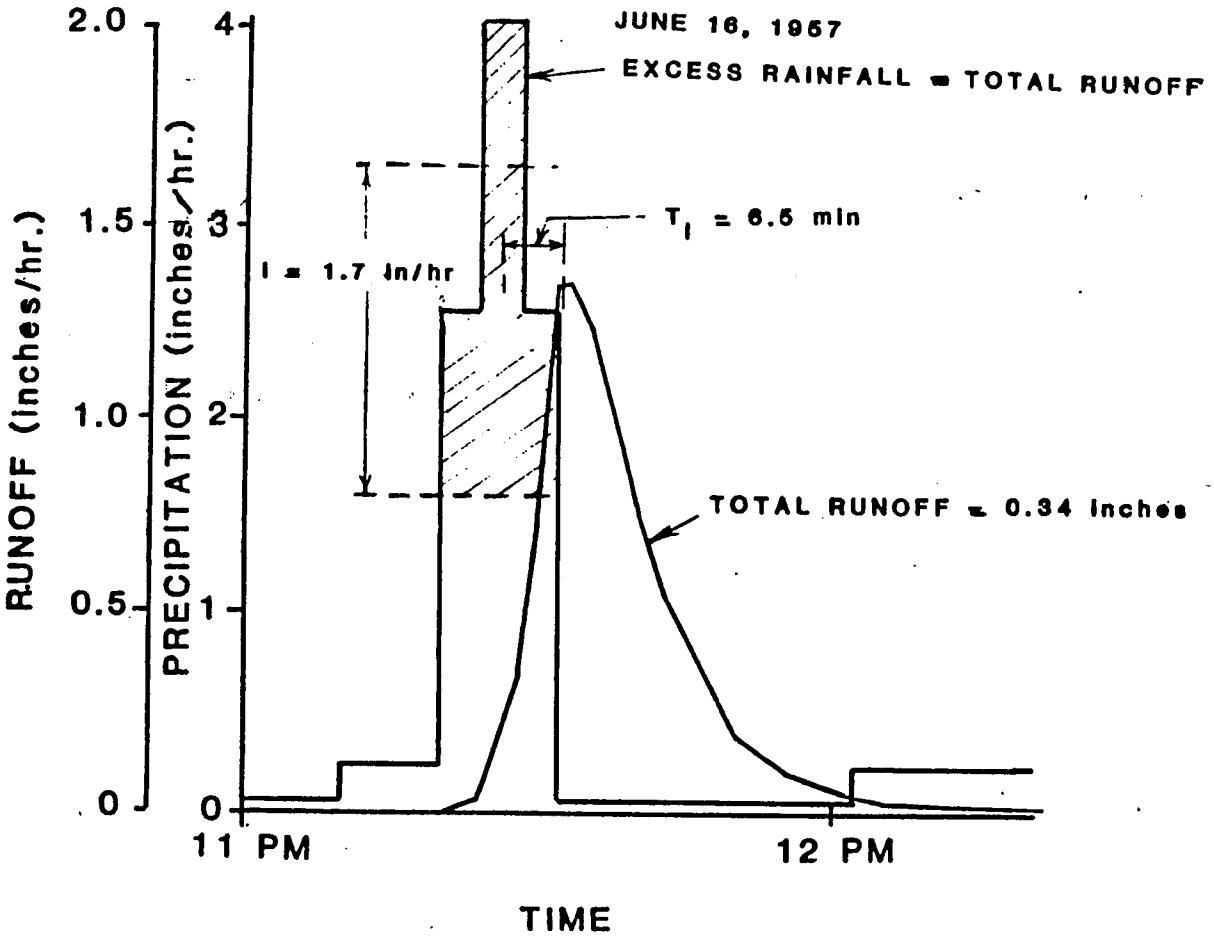


Figure 2. WATERSHED 1-H IN HASTINGS, NEBRASKA.
RAINFALL EVENT OF JUNE 16, 1957.
AVER. EXCESS RAINFALL INTENSITY i = 1.7 in/hr
TIME OF CONCENTRATION T_c = 6.5/0.6 = 10.8 min.

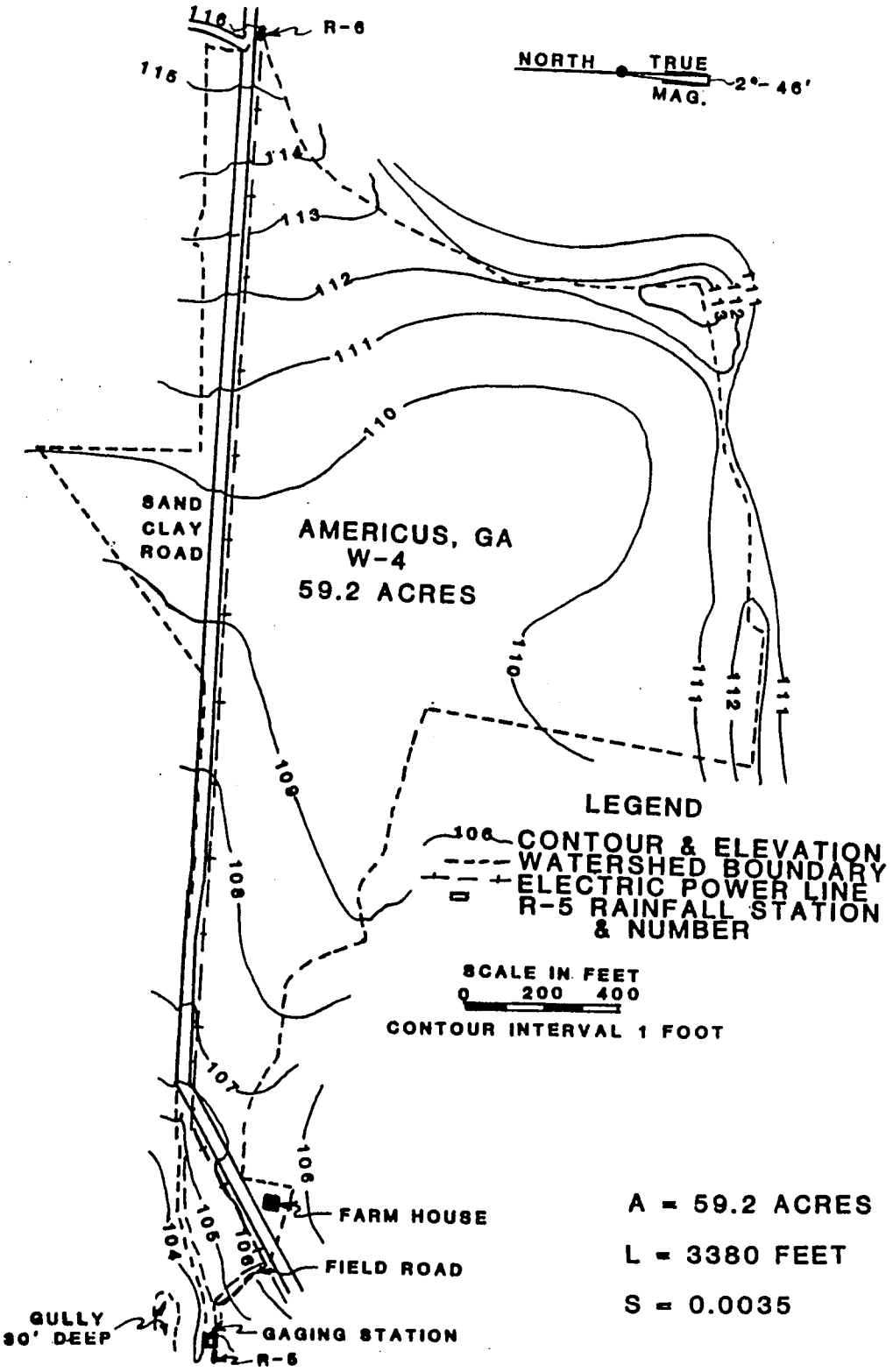


Figure 3. WATERSHED W-IV IN AMERICUS, GEORGIA. PLAN VIEW.

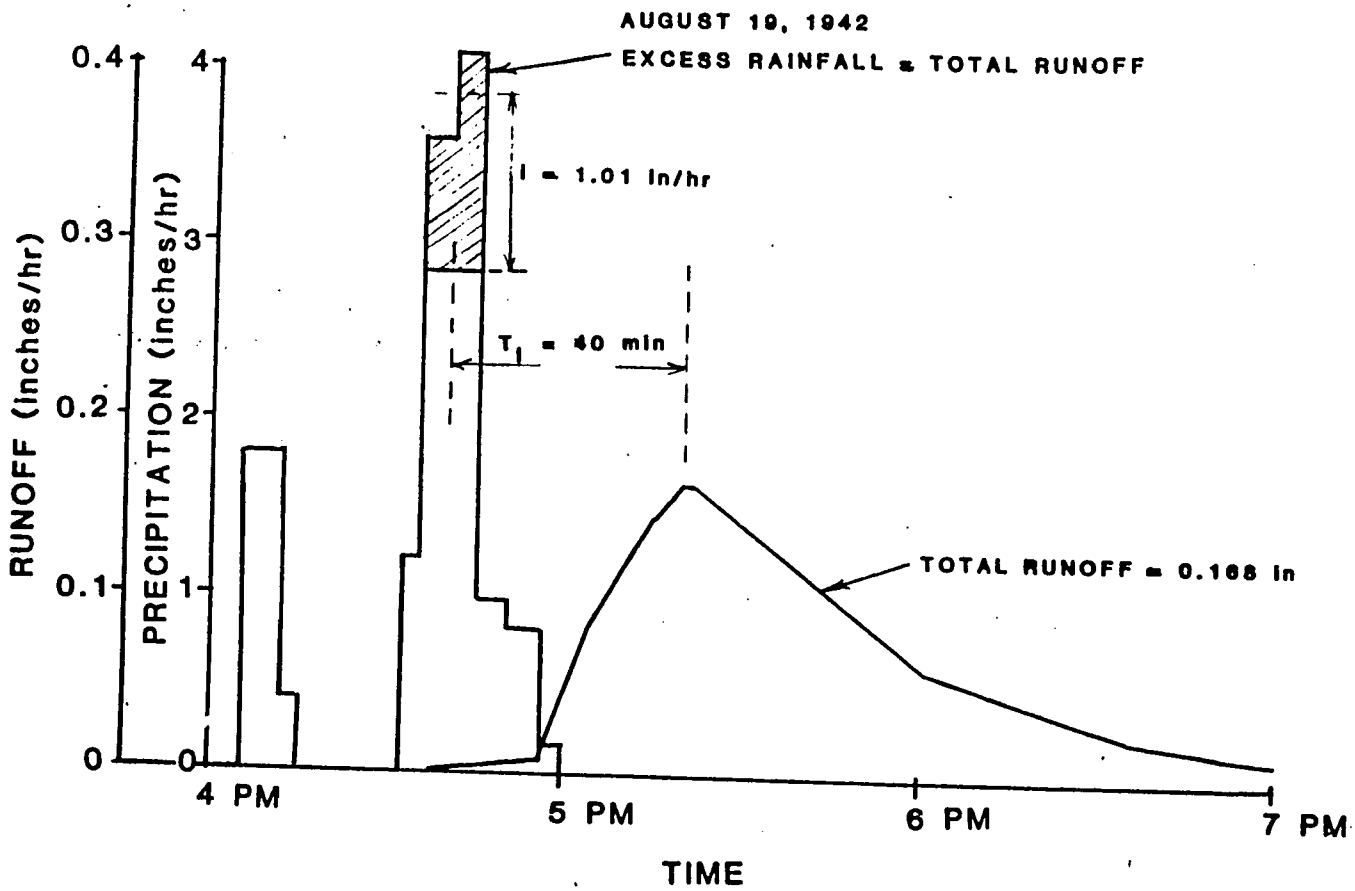


Figure 4. WATERSHED W-IV IN AMERICUS, GEORGIA
RAINFALL EVENT OF AUGUST 19, 1942
AVER. EXCESS RAINFALL INTENSITY i = 1.01 in/hr
TIME OF CONCENTRATION T_c = 40/0.6 = 67 min.

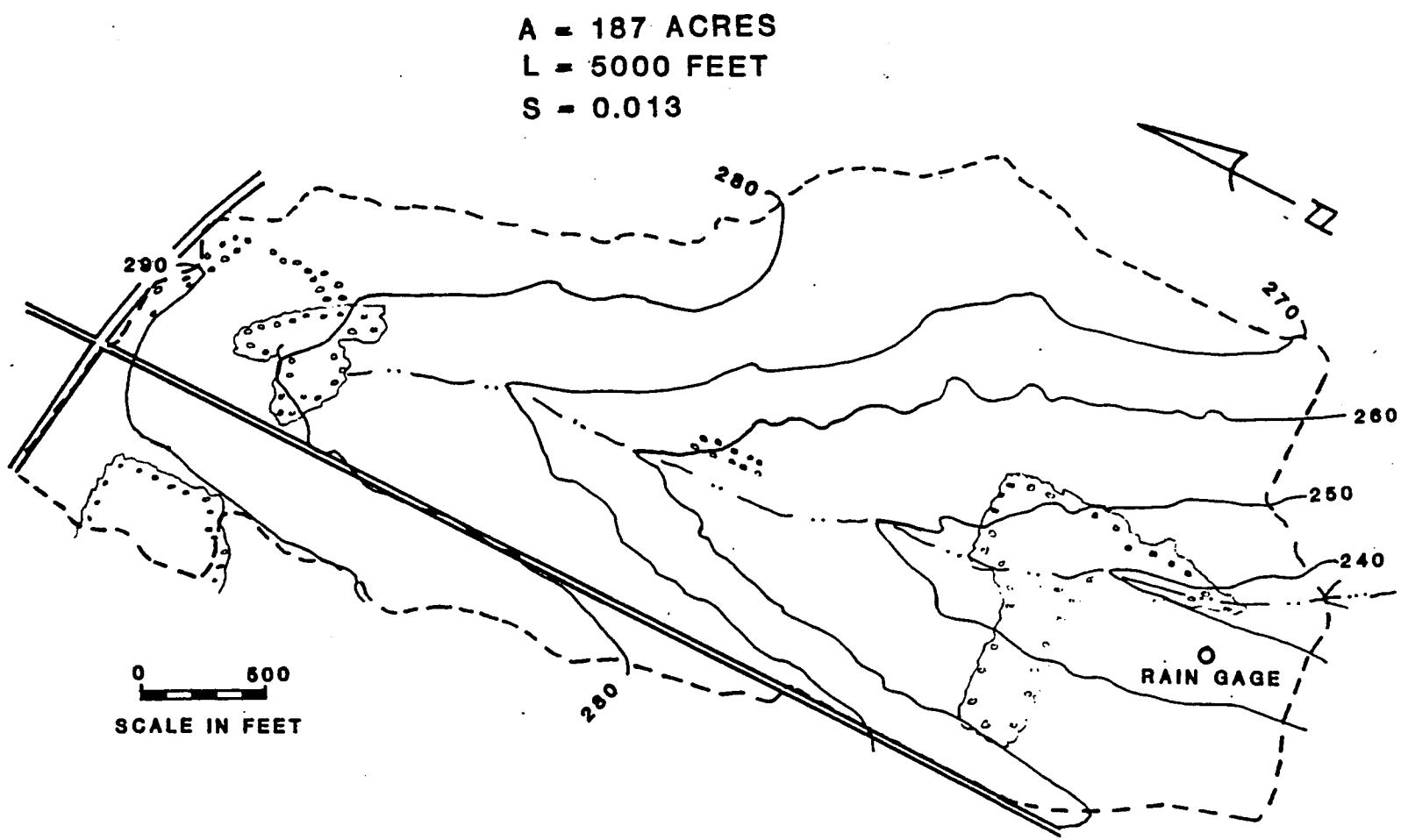


Figure 5. WATERSHED W-I IN HAMILTON, OHIO. PLAN VIEW

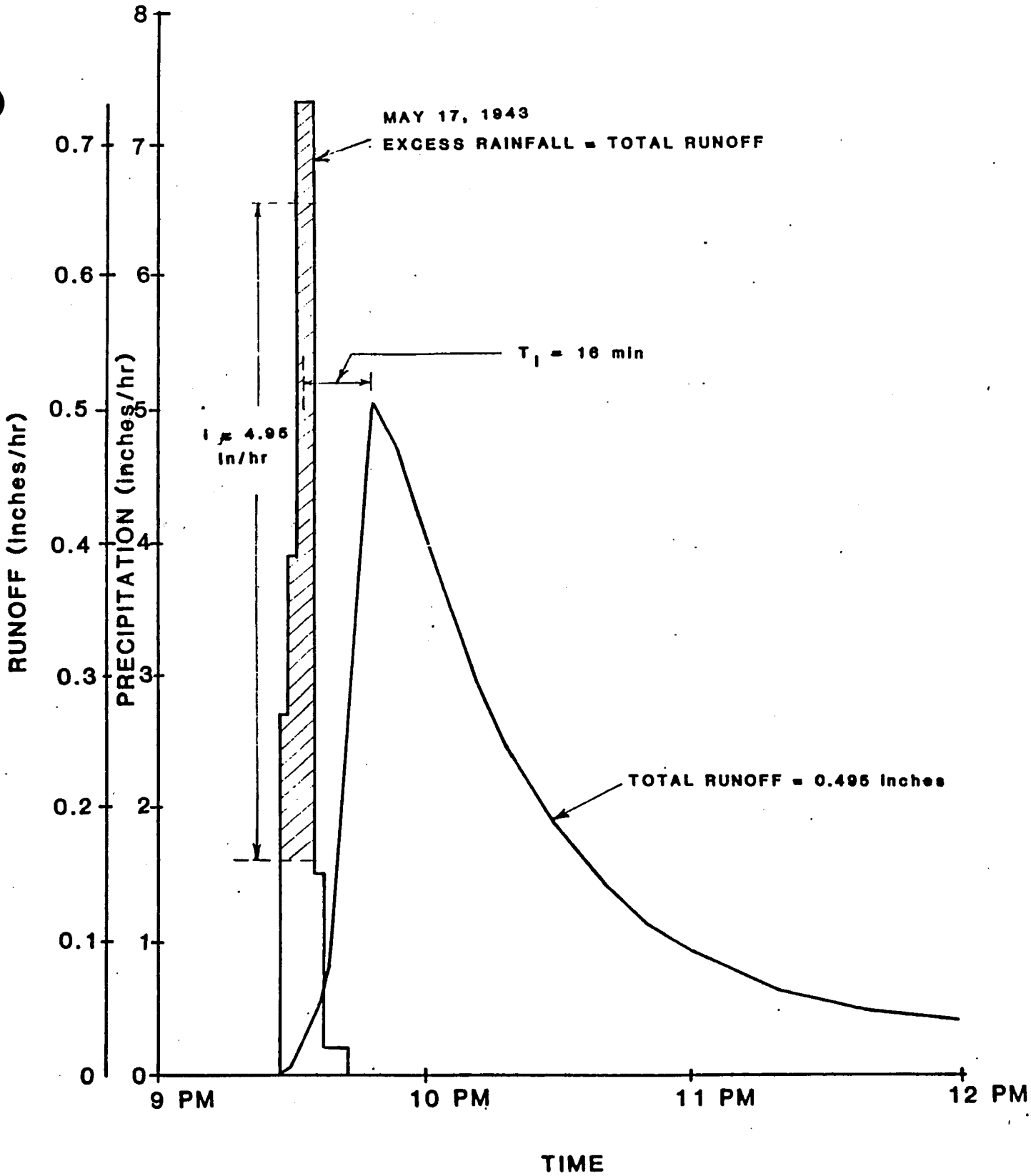


Figure 6. WATERSHED W-I IN HAMILTON, OHIO
RAINFALL EVENT OF MAY 17, 1943
AVER. EXCESS RAINFALL INTENSITY i = 4.95 in/hr
TIME OF CONCENTRATION T_c = 16/0.6 = 27 min.

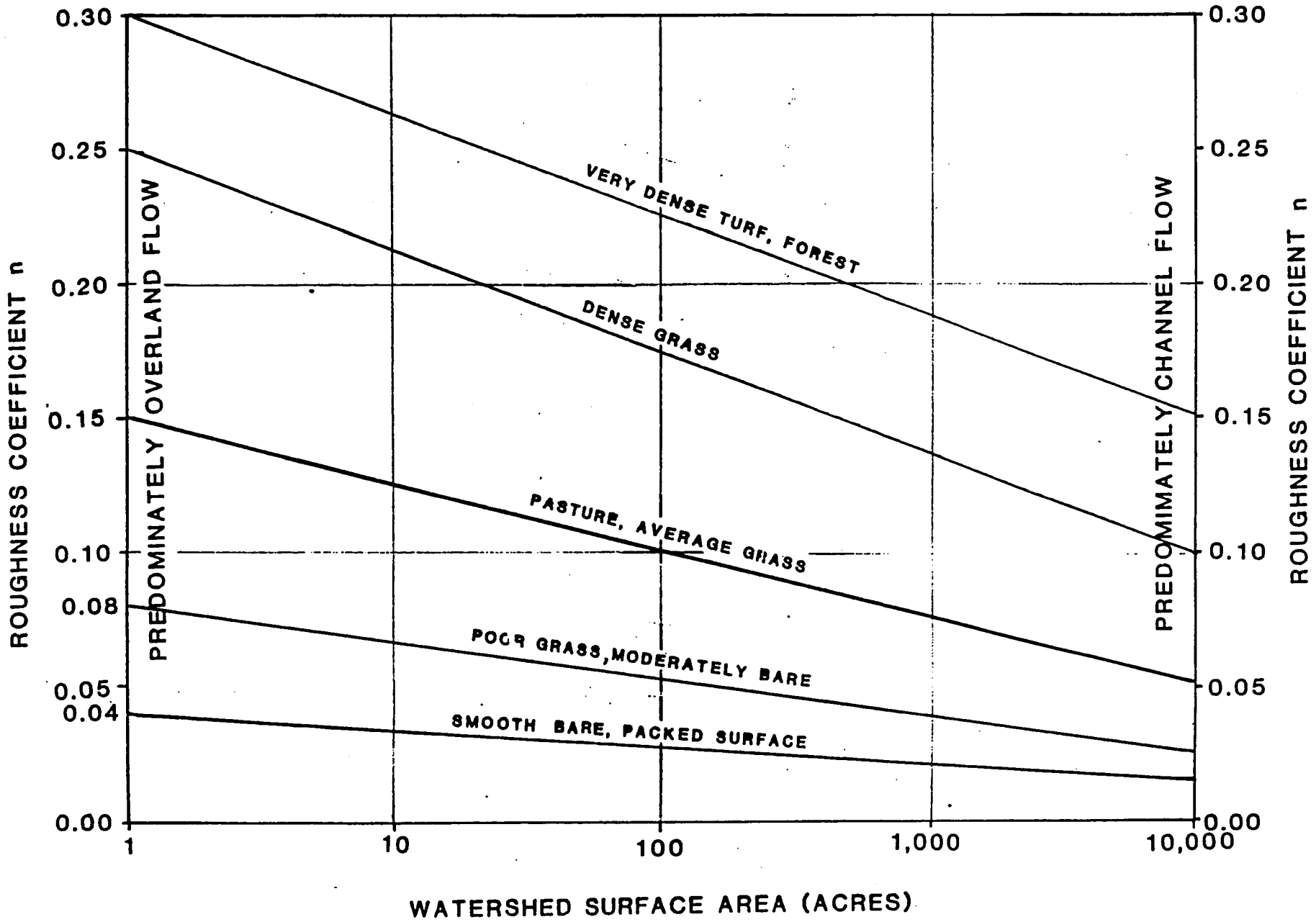


Figure 7. THE EFFECT OF WATERSHED AREA ON THE ROUGHNESS COEFFICIENT.

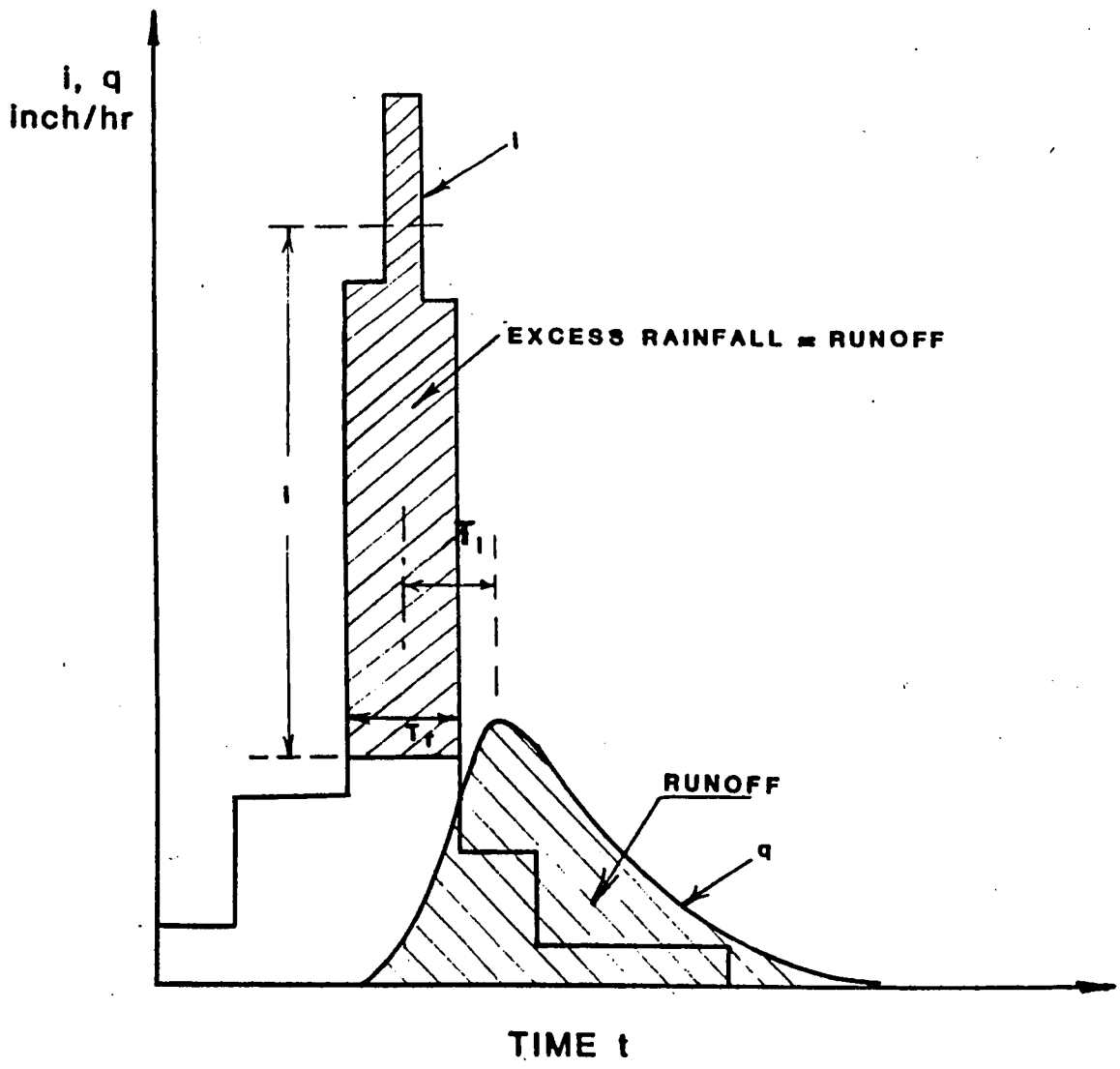
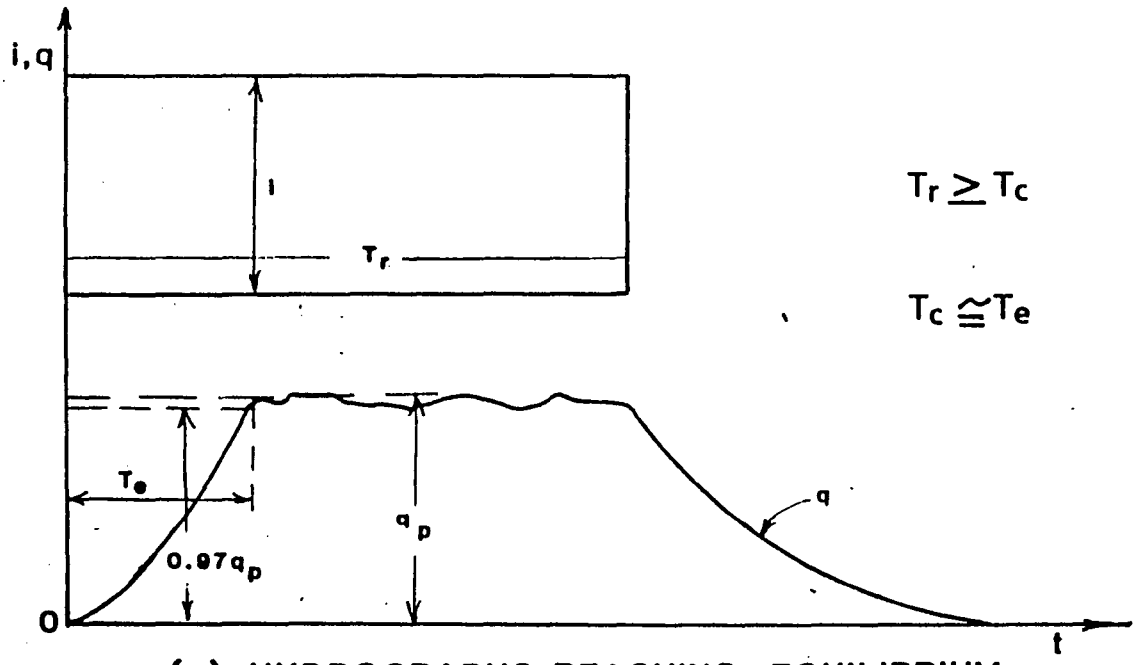
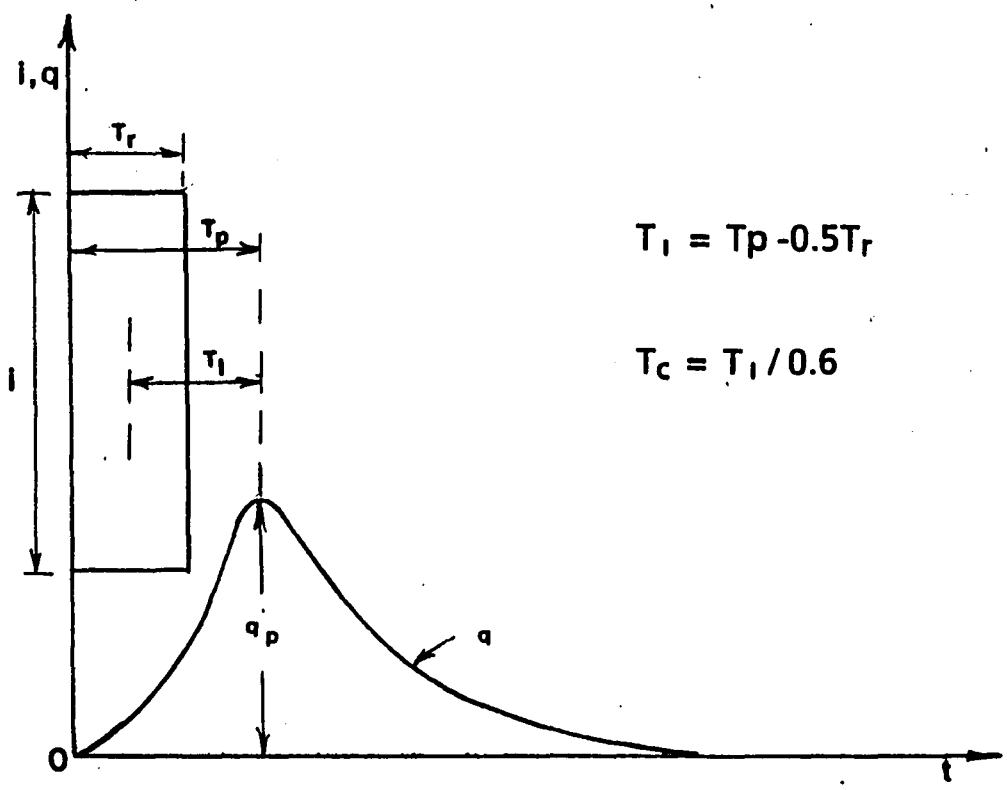


Figure 8. ESTIMATION OF EXCESS RAINFALL INTENSITY i, TIME OF EXCESS RAINFALL T_r, and LAG TIME T_l.



(a) HYDROGRAPHS REACHING EQUILIBRIUM



(b) NON-EQUILIBRIUM HYDROGRAPHS WITH PEAK DISCHARGE

Figure 9. ESTIMATION OF TIME OF CONCENTRATION, T_c, FROM A MEASURED HYETOGRAPH AND HYDROGRAPH.

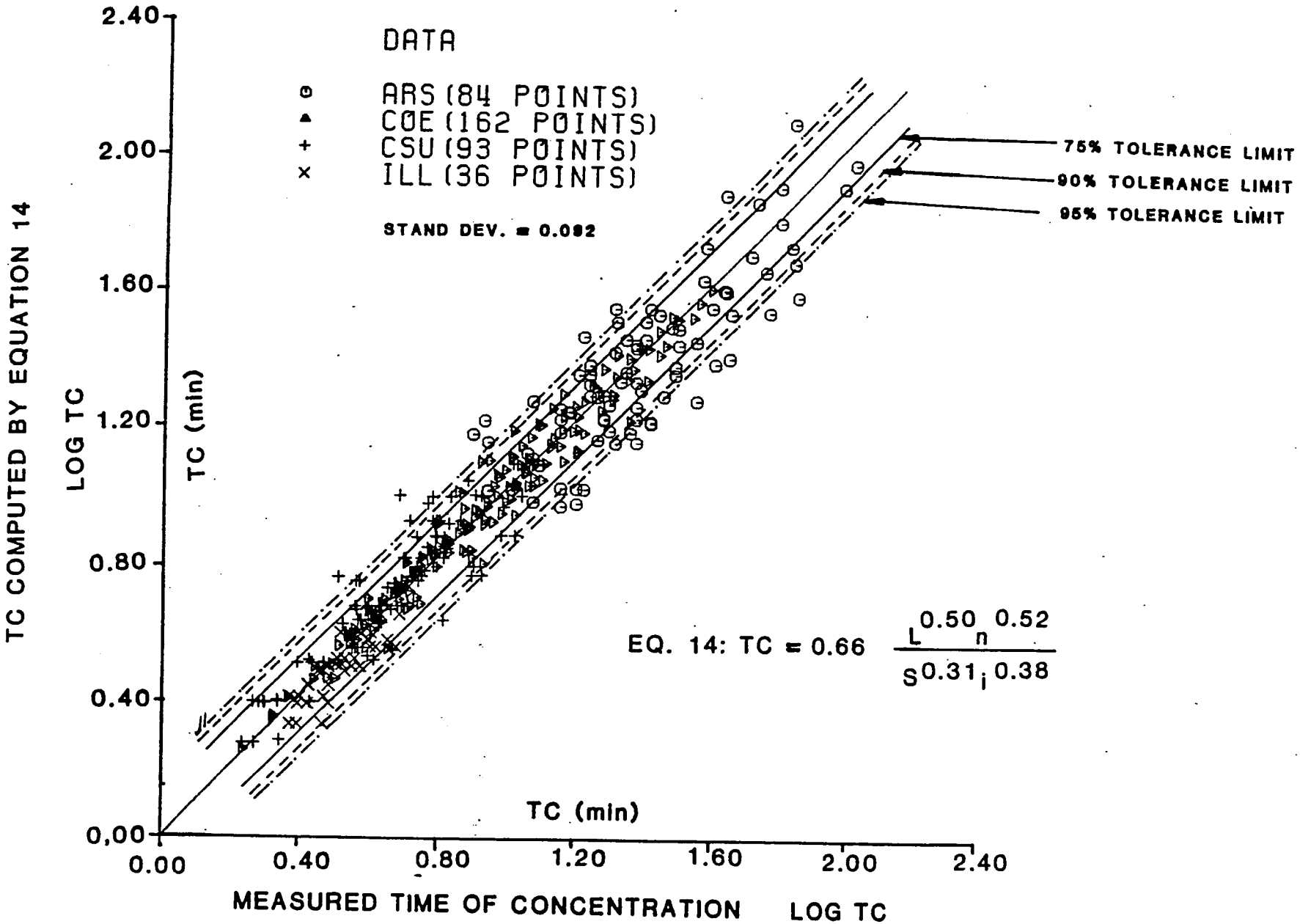


Figure 10. TIMES OF CONCENTRATION COMPUTED BY THE FOUR-PARAMETER EQUATION 14 VERSUS MEASURED VALUES.

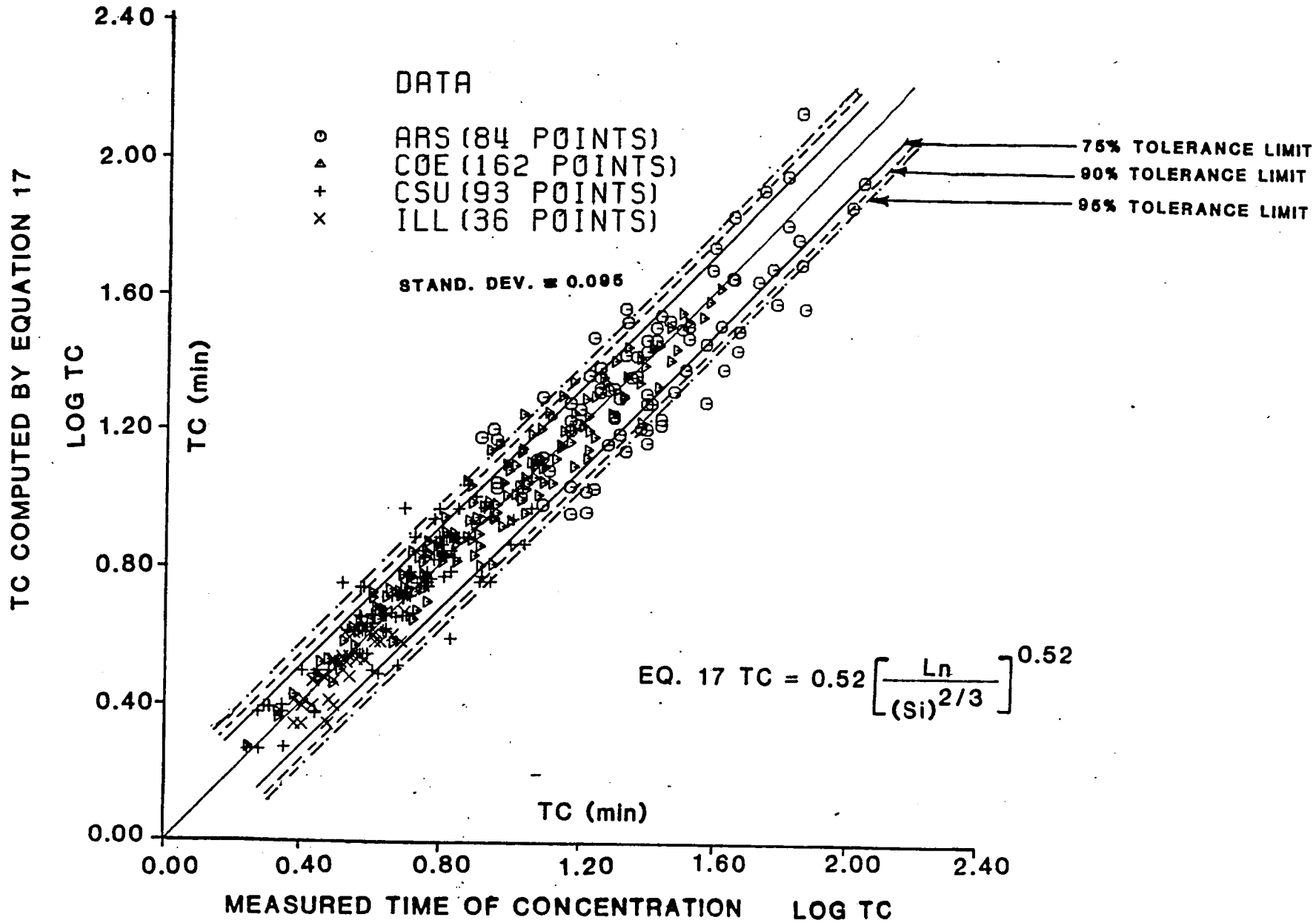


Figure 11. TIME OF CONCENTRATION COMPUTED BY THE ONE-PARAMETER EQUATION 17 VERSUS MEASURED VALUES.

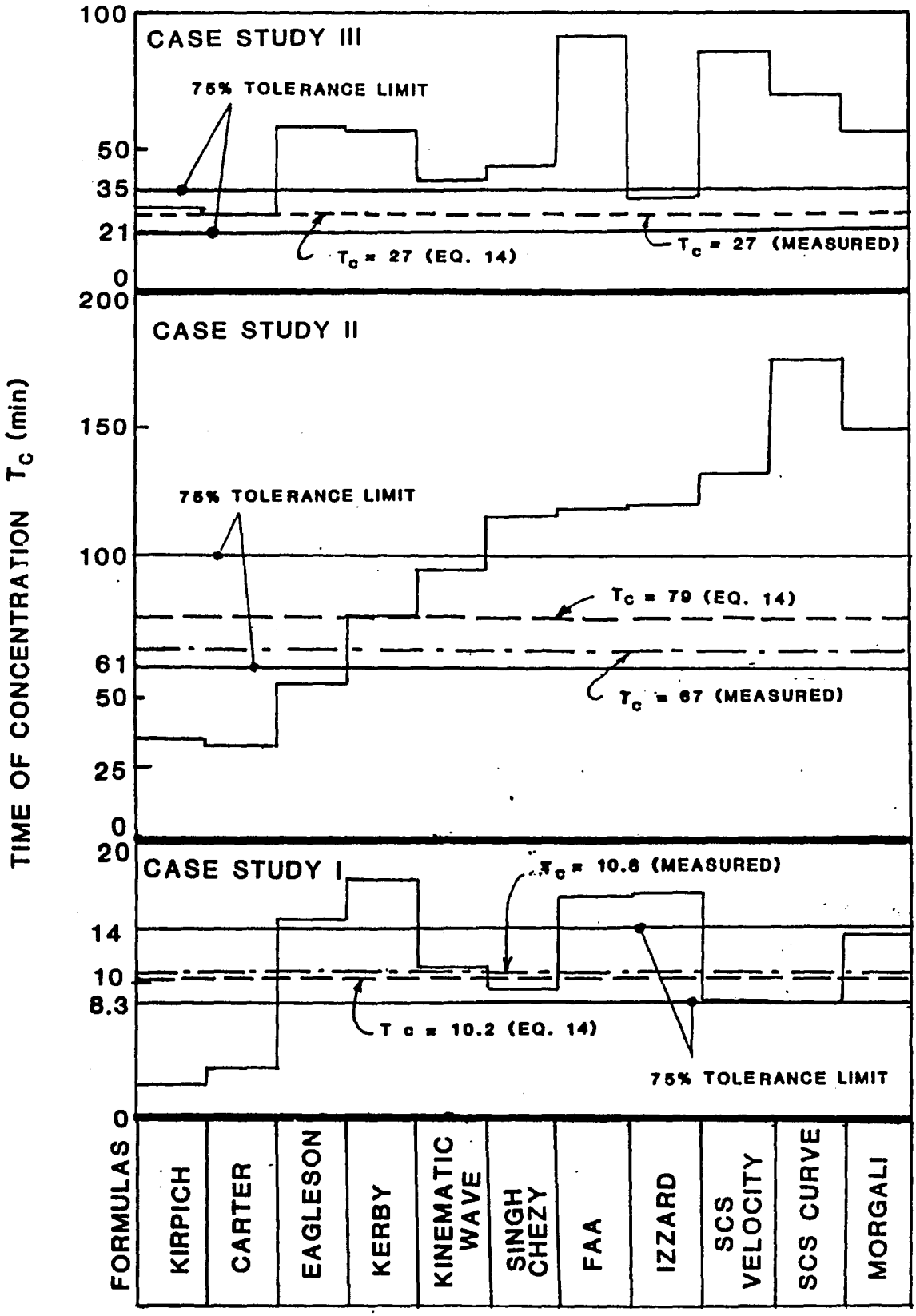


Figure 12. COMPARISON OF TIMES OF CONCENTRATION FOR THREE CASE STUDIES

APPENDIX 3-K

Work sheet for development of R equation.

OPTION?

data file REG 14.DAT

MULTIPLE REGRESSION

REGRESSION NUMBER 1
R = -.8995714
COEFFICIENT OF DETERMINATION = 0
STD DEVIATION OF ESTIMATE = .7423144

REGRESSION NUMBER 2
R = -.5943793
+ .7794263 TC
COEFFICIENT OF DETERMINATION = .4371927
STD DEVIATION OF ESTIMATE = .5730329

REGRESSION NUMBER 3
R = -.3548567
+ 1.310766 TC
+ -.2873964 A
COEFFICIENT OF DETERMINATION = .4878506
STD DEVIATION OF ESTIMATE = .5634592

FINAL SOLUTION

REGRESSION NUMBER 4
R = -.9984523
+ 1.10563 TC
+ -.5747052 A
+ .8001565 L
COEFFICIENT OF DETERMINATION = .535462
STD DEVIATION OF ESTIMATE = .5542288

$R = .37\ TC^{1.11}\ A^{-.57}\ L^{.80}$

ACTUAL	PREDICTED	DIFFERENCE	%DIFFERENCE	
-.4462872	-.8345173	.3882301	-86.99109	
-.8209805	-.5993183	-.2216622	26.99969	
-1.514128	-.8961038	-.618024	40.81716	
-1.139434	-.9723845	-.1670498	14.66077	
-1.966113	-1.078605	-.8875076	45.14022	
-1.021651	-9.230506E-02		-.9293462	90.96511
-.3011051	-.6534317	.3523266	-117.0112	
-.4155155	-1.131118	.7156026	-172.2205	
-1.237874	-.9949004	-.2429741	19.62833	
-1.171183	-1.290504	.119321	-10.18807	
-1.171183	-1.552032	.3808487	-32.51829	
1.156881	.5336636	.6232176	53.87049	
-1.049822	-1.274019	.2241972	-21.35573	
-2.207275	-1.587264	-.6200109	28.08943	
-.5447272	-.2481372	-.29659	54.44744	
-.5108257	-.7142643	.2034387	-39.82547	
-.6733447	-.9646442	.2912995	-43.26158	
-.3424904	-1.016683	.6741931	-196.8502	
-1.714798	-1.725288	1.048958E-02		-.6117095