TASK 1

HYDROLOGY MAN.
MARICOPA CO. 11-87

1004.035

EVALUATION CRITERIA

Clark S-Graph

Practicality

1. Is there adequate technology (computerized models) available to use this procedure?

2. Will the users understand the underlying concept and be able to implement the methodology confidently?

3. Is this the most practical level of technology that can be used for design and planning of county-wide flood control facilities?

4. Will the procedure be readily accepted by; the
   a.) FCD staff
   b.) engineering community
   c.) developers (cost effective to them)
   d. staffs of other municipalities?

5. Will it provide results that are comparable with those used by other state and federal agencies and their projects?
   Corps of Engineers
   SCS
   ADWR (Dam Safety)
   ADOT

6. Will it be defensible in court and public hearing?

7. Can procedures be developed to select and/or calculate input parameters based on readily obtainable information?

8. Can all physiographic watershed conditions be adequately represented by this method?

Accuracy

1. Will this procedure result in the best estimate of the design event (100-yr flood peak, volume, and hydrograph shape)?

2. Will this procedure result in the best estimate of other frequency flood events; less than 100-yr flood and PMF?

3. Will this method be flexible enough to provide adequate modeling for all types of physiographic watersheds in Maricopa County?

4. How will it compare with results from other methods and past projects?

Reproducibility

1. Will the procedure be flexible enough to allow "appropriately" educated and experienced hydrologists to make professional decisions in arriving at the "best" flood hydrology?

2. Will the procedure be rigid enough to assure that consistant results will be obtained by "all" users?

3. Can procedures be developed such that users will be able to obtain consistent results that assures the acceptance of their studies if the procedures are followed?

4. Can procedures be developed such that there is a minimum of subjective decisions concerning the selection and/or calculation of parameters?

Flood Control District of Maricopa County
Unit-Hydrograph Study
Contract FCD 87-23

Project Review Meeting
for Completion of Task I (Data Analysis)
2 November 1987

AGENDA

1. Project status report
   a. Scope-of-Service
   b. Budget

2. Review of basic data
   a. Sources of basic data and discussion
   b. Watersheds
   c. Criteria for selection of storm events for analysis

3. Presentation of example of typical data analysis and flood reconstitution
   a. Determination of effective impervious area
   b. Preliminary determination of R by recession analysis
   c. Digitization of hydrograph
   d. Digitization of rainfall distribution(s)
   e. Selection of representative rainfall distribution
   f. Flood reconstitution using the HEC-1 parameter optimization option
   g. Iterative process to make final selection of parameters; T_c, R, and Time-Area relation

4. Consideration of special problems
   a. Assumption that valid rainfall and runoff data have been obtained
      1.) rainfall has been recorded at appropriate time interval to adequately represent the rainfall intensity
      2.) the stage-discharge rating curve is valid at all recorded stages
   b. Assumption that rainfall is uniform over the watershed
   c. Assumption that the selected time distribution of rainfall is valid
   d. Estimation of effective impervious area
   e. Selection of representative Time-Area relation

5. Discussion of results of flood reconstitutions
   a. Clark unit-hydrograph parameters; T_c, R, and Time-Area relation
   b. S-graphs
   c. Rainfall loss parameters

6. Discussion of comparative advantages and disadvantages of the Clark unit-hydrograph and the S-graph

7. Discussion of selection of either the Clark unit-hydrograph or the S-graph as a standard

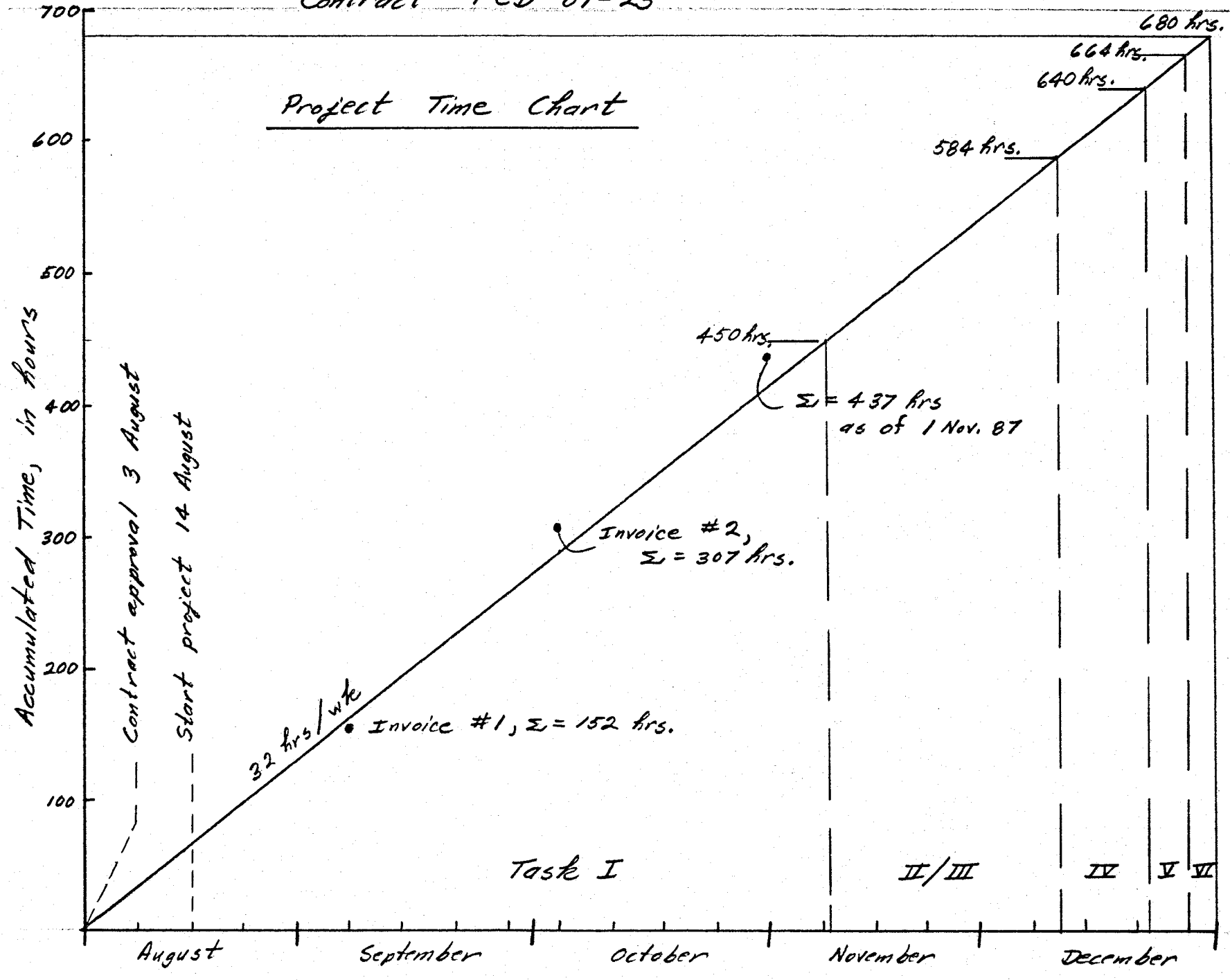
8. Schedule for completion of Unit-Hydrograph Study

9. Review of final draft of S-Graph Report
   a. Comments of preliminary draft from FCD staff
   b. Changes that have been incorporated in final draft
   c. Discussion of final draft
   d. Discuss copyright
   e. List of individuals to receive a copy of final report
   f. Publishing cost of final report
   g. Finished?

10. How does unit-hydrograph and S-graph study fit into overall plan for a hydrology manual? (See Task IV.C)

11. Contract FCD 86-36 is to terminate 31 December 1987.
    Original budget was $25,000.
    (2) studies were performed ($8,295 and $4,000)
    Balance is $12,705.
    Is there a desire to extend this into 1988?

Contract FCD 87-23



Watershed (1)			Area acres (2)	Eff. Imp. Area % (3)	# of raingages recording (4)	# of raingages non-recording (5)	# of events analyzed (6)
Albuquerque –	Villa del Oso	AVDØ	33.3	16.4	1	0	2
	Academy Acres	AAA	79.4	16.3	2	0	2
	Taylor Ranch	ATR	87.0	9.6	2	0	1
	La Cueva Arroyo	ALA	57.6	0	1	0	3
	Camino Arroyo	ACA	57.0	0	1	0	2
	N. Camino Arroyo	ANCA	134.4	0	1	0	2
Denver –	116th Ave	D116	170.0	13.3	3	0	2
	Villa Italia	DVI	77.0	82.0	1	0	1
	Concourse D	DCD	96.0	90.0	1	0	1
	Goose Creek	DGC	441.6	15.4	1	0	1
	Sand Creek	DSC	185.6	24.0	1	0	2
Tucson –	High School	THS	576.0	11.3	4	1	2
	Arcadia	TAR	2240.	10.9	7	3	4
	Railroad	TRR	1472.	17.0	3	3	2
	Atterbury	TAT	3181.	3.0	1	8	3
Walnut Gulch –	W-4	4–	560.	0	4	0	2
	W-8	8–	3830.	0	17	0	2
	W-11	11–	2035.	0	10	0	2
	W-15	15–	5912.	0	15	0	1
	W-103	103–	8.3	0	1	0	2
	W-111	111–	143.	0	2	0	3
Wyoming –	W.F. Dry Chey. Ck.	WCU	441.6	0	1	0	2
	W.F. Dry Chey. Trib.	WC	1184.0	0	1	0	2
	Dead Horse Ck.	WDH	979.2	0	1	0	1
	East Teapot Ck.	WET	3482.0	0	1	0	1
	Dugout Ck.	WD	454.4	0	1	0	1
	Headgate Draw	WHD	2124.8	0	1	0	1
	Medicine Bow Trib.	WMB	1926.4	0	1	0	1

Number of watersheds = 28

Number of events = 51

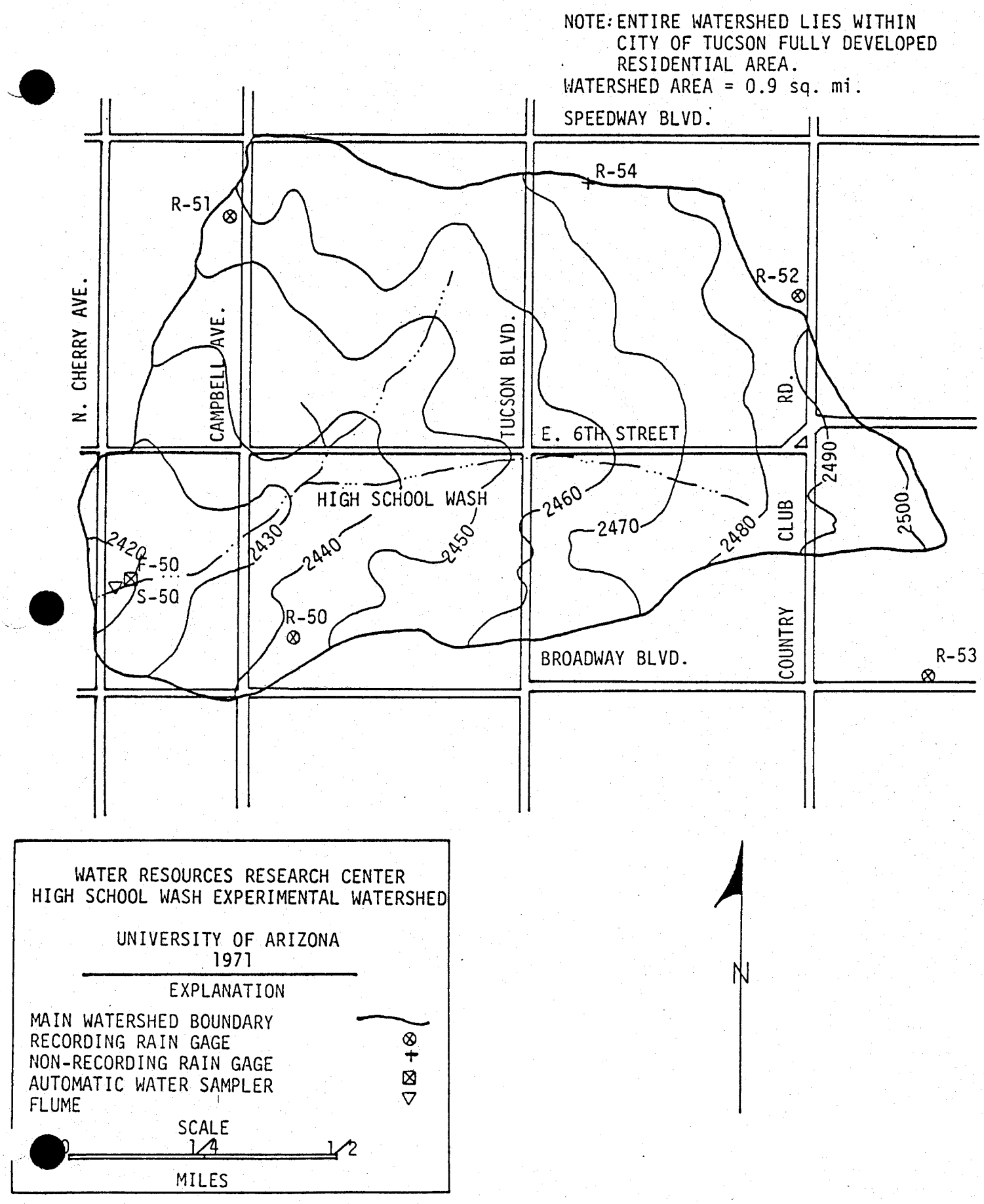


FIGURE 3. High School Wash Experimental Watershed.

9 Oct 87

High School Watershed

Storm Event	Hydrograph Type*	Peak cfs	Rainfall recorder gages (✓ if records available) R-50	R-51	R-52	R-53	Nonrecorder Gages R-54	Data comments	Analyzed? Comment
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		
10 Aug 68	S	486	1.40	1.52		.83		*no rainfall charts	
1 Aug 69	S	341	1.15	.68		1.03	.85	*no rainfall charts	
19 July 70	S	255	.26			.46		*no rainfall charts	
20 July 70	S	243	.49			.84		*no rainfall charts	
11 Aug 70	S	408	.58	1.17		1.45		*no rainfall charts	
8 Aug 71	S	663	1.20	1.40	1.65	1.32	1.70	possible hydrograph error *no rainfall charts	
12 Aug 72	S	790	1.93✓	1.87✓	1.25✓	1.52	1.83 @ R-55	R-53 chart missing possible hydrograph error	
13 Aug 80	S	360	1.72	1.75✓	2.15✓	1.40✓		R-50 chart missing	Yes
25 July 82	S	464	.96	.93✓	.50✓	.20✓		R-50 chart missing	partial area rainfall
11 Sept 82	S	331	2.00	1.60✓	1.93✓	1.80✓		R-50 chart missing	Yes

Type – Single peak (S)
multiple peak (M)
Flat peak (F)

4 Oct 87

Analysis of Effective Impervious Area
High School Watershed

Storm Date	Rainfall Avg. inches	Rainfall Max. inches	Runoff Volume ac-ft	Runoff Q_p cfs	Runoff % of rainfall	A_e acres
(1)	(2)	(3)	(4)	(5)	(6)	(7)
10 April 68	.163	.21	.659	7.5	8.0	48.5
20 April 68	.127	.14	.198	3.3	3.2	18.7
26 July 68	.187	.25	1.454	33.0	15.5	93.3
30 July 68	.282	.36	1.454	21.0	10.3	61.9
31 July 68	.157	.18	1.637	39.5	20.4	125.1
14 Nov 68	.762	.79	3.283	21.0	8.5	51.7
14 Nov 68	.437	.51	5.436	73.5	24.5	144.1
26 Dec 68	.450	.46	1.459	8.4	6.4	38.9
14 Jan 69	.623	.65	1.175	3.3	3.7	22.6
5 May 69	.520	.55	3.597	40.0	13.6	83.0
9 Nov 69	.543	.55	2.001	15.5	7.4	44.2
10 Nov 69	.291	.36	1.966	36.0	13.4	81.1
28 June 70	.498	.53	2.087	33.0	8.2	50.3
4 Sept 70	1.270	1.40	8.654	34.6	13.5	81.8
15 April 71	.397	.45	.939	16.5	4.8	28.4
29-30 July 71	.593	.75	5.056	72.3	16.9	102.3
12 Aug 71	.223	.26	1.657	6.2	14.8	89.2
30 Sept 71	.220	.26	.286	2.6	2.7	15.6
17 Oct 71	.983	1.05	6.047	28.6	12.1	73.8
15 Nov 71	.276	.35	.526	9.0	3.6	22.9
16 Nov 71	.494	.53	3.317	23.5	13.2	80.6
4 Dec 71	.636	.66	5.207	37.5	16.2	98.2
7 Dec 71	.780	.82	3.389	11.8	8.6	52.1
30 May 72	.420	.56	2.007	39.6	9.5	57.3
21 June 72	.435	.50	3.080	80.9	14.0	85.0
15 July 72	.328	.40	1.331	27.5	7.9	48.7
17 July 72	.188	.20	.703	5.3	7.5	44.9
5 Aug 72	.620	.80	3.523	39.6	11.3	68.2
11 Aug 72	.454	.60	3.309	77.3	14.3	87.5
7 Sept 72	.266	.34	2.023	44.5	15.0	91.3
18 Sept 72	.318	.35	2.205	44.9	13.8	83.2
3 Oct 72	.503	.53	1.921	11.4	7.6	45.8
4 Oct 72	.452	.57	4.000	42.7	17.7	106.2
5 Oct 72	.365	.42	2.326	19.5	12.6	76.5
19 Oct 72	.180	.18	.788	5.7	8.9	52.5
11 Nov 72	.649	.67	4.750	51.7	14.5	87.8
17 Nov 72	.651	.66	3.445	17.2	10.5	63.5
28 Dec 72	.262	.27	.988	19.0	7.6	45.3

continued - High School

4 Oct 87

(1)	(2)	(3)	(4)	(5)	(6)	(7)
7 Mar 73	.445	.45	2.999	30.8	13.3	80.9
12 Mar 73	.466	.58	2.214	5.1	9.4	57.0
14 Mar 73	.609	.62	5.810	33.6	18.9	114.5
12 June 73	.342	.35	1.148	18.4	6.7	40.3
30 June 73	.360	.45	2.197	32.7	11.9	73.2
8 Mar 74	.362	.40	.866	8.1	4.7	28.7
18 July 74	.490	.60	2.238	43.3	9.0	54.8
29 oct 74	.710	.80	6.365	44.9	17.7	107.6
29 Jan 75	.407	.45	1.454	10.3	7.1	42.9
8 Mar 75	.217	.25	.989	20.1	9.0	54.7
11-12 Mar 75	.557	.65	3.013	21.2	10.7	64.9
7-8 Apr 75	.300	.34	.399	3.4	2.6	16.0
2 July 75	.390	.45	1.676	25.4	8.5	51.6
7 July 75	.217	.25	1.240	32.7	11.2	68.6
7 July 75	.198	.24	1.137	7.0	11.3	68.9
28-29 Nov 75	.345	.37	1.711	26.1	9.8	59.5
23 Dec 75	.325	.38	1.934	11.3	11.7	71.9
20 May 76	.300	.35	2.824	61.6	18.6	113.0
9 July 76	.205	.25	.729	13.8	7.0	42.7
24 Aug 76	.310	.35	1.256	28.6	8.0	48.6
21 oct 76	.480	.58	2.086	44.5	8.6	52.2
13-14 Nov 76	.320	.35	.907	5.3	5.5	34.0
31 Dec 76	.950	1.02	6.650	17.9	13.8	84.0
8 Jan 77	.45	.49	2.052	9.0	9.0	54.7
21-22 Jan 77	.56	.65	3.303	27.4	11.6	70.8
29-30 Jan 77	.47	.50	3.455	20.0	14.0	88.2
26-27 Mar 77	.67	.76	3.243	24.8	9.0	58.1
2 Apr 77	.21	.25	.370	4.4	3.4	21.1
9 oct 77	.43	.50	4.717	87.7	21.6	131.6
6-7 Nov 77	.40	.50	1.647	7.8	8.1	49.4

continued - High School

4 oct 87

(1)	(2)	(3)	(4)	(5)	(6)	(7)
10 Jan 78	.67	.80	5.85	43.8	16.7	101.7
15-16 Jan 78	.80	.83	6.780	25.4	16.6	101.7
17 Jan 78	.53	.60	3.724	18.4	13.9	84.3
1 Feb 78	.38	.40	4.83	86.9	25.0	152.5
11-12 Feb 78	1.05	1.12	7.758	19.5	14.6	88.7
13-14 Feb 78	.35	.40	.887	2.5	4.9	30.4
27 Feb - 2 Mar 78	.81	.92	3.165	15.1	7.7	46.9
5-6 Mar 78	.18	.20	.295	2.1	3.2	19.7
14-15 Nov 78	.36	.45	2.45	37.5	13.3	81.7
23-25 Nov 78	1.35	1.45	9.73	32.7	14.2	86.5
6 Dec 78	.25	.30	.53	6.7	4.0	25.4
17-18 Dec 78	1.57	1.70	11.43	49.4	14.3	87.4
29-31 Dec 78	1.55	1.75	9.697	29.01	12.3	75.1
5-7 Jan 79	.68	.75	3.112	14.2	9.0	54.9
16-17 Jan 79	1.09	1.18	10.88	50.6	19.6	119.8
24-25 Jan 79	.72	.75	2.97	15.9	8.3	49.5
4-5 Feb 79	.48	.58	3.42	21.2	14.6	85.5
20-21 Mar 79	.51	.57	3.64	34.1	13.7	85.6
Nov 79	.18	.20	.75	16.5	7.8	50.0
13-17 Feb 80	1.69	1.80	15.159	48.3	17.7	107.6
12-13 July 80	.57	.65	2.440	17.0	8.4	51.4
25 July 80	.23	.26	.787	21.2	6.5	41.1
25-26 Sept 80	1.12	1.20	9.291	80.2	16.3	99.5
15-16 Oct 80	.40	.47	1.358	16.9	6.8	40.7
11-12 Jan 81	.548	.62	2.609	15.1	9.4	57.1
8-10 Feb 81	.995	1.02	3.57	14.2	7.0	43.1
1-4 Mar 81	1.08	1.50	5.56	28.6	10.2	61.8
5-6 Mar 81	.44	.50	3.097	22.3	13.9	84.5
30 Apr 81	.255	.30	1.100	35.1	8.5	51.8
11-12 July 81	.223	.27	.63	12.5	5.5	33.9
29 July 81	.295	.38	1.409	21.2	9.4	57.3
29 Nov 81	.743	.83	3.280	35.1	8.7	53.0

continued - High School

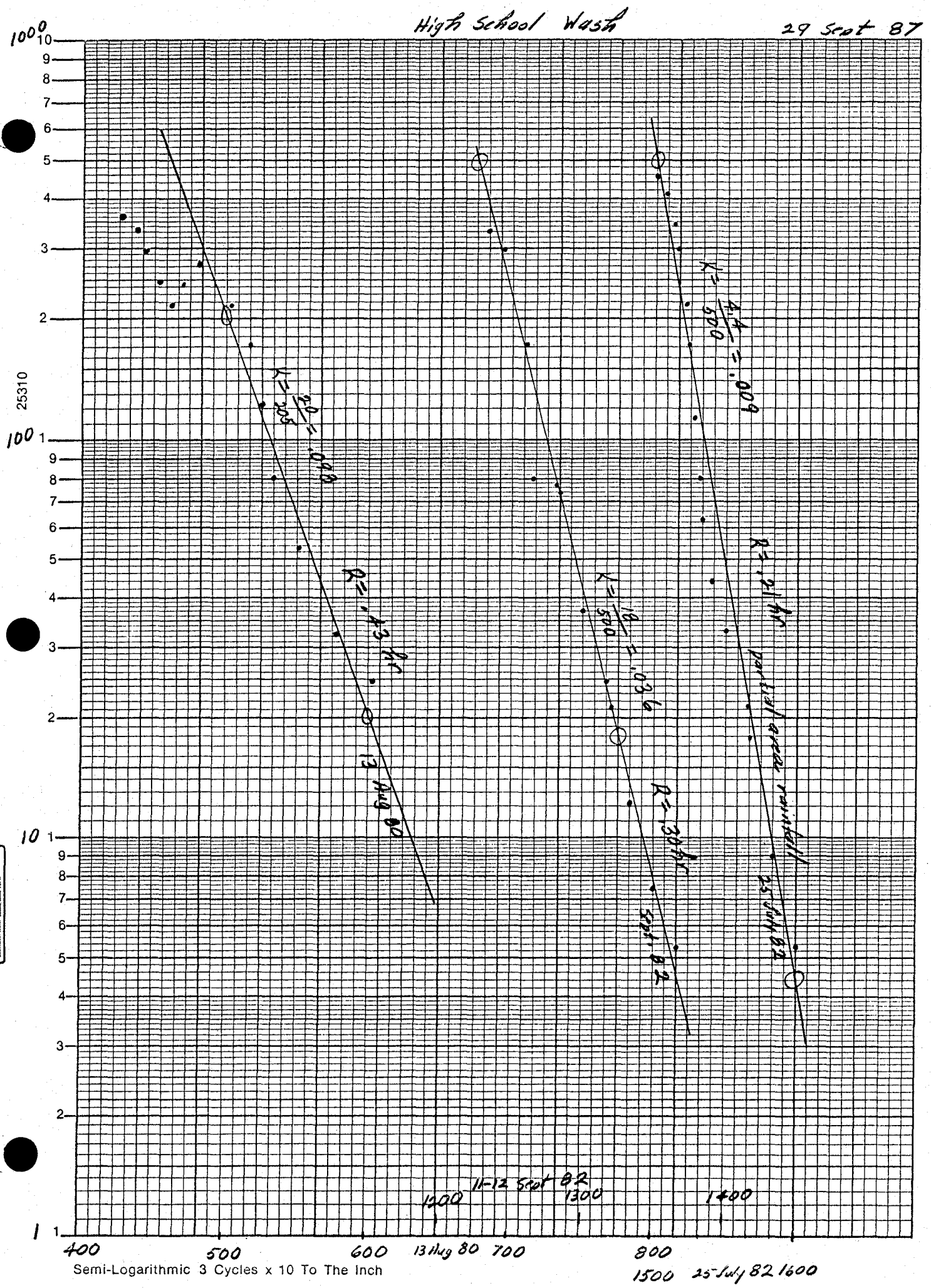
4 oct 87

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1-2 Jan 82	.488	.56	1.461	16.0	5.9	35.9
10-12 Jan 82	.365	.45	1.591	26.8	8.5	52.3
21 Jan 82	.400	.52	1.918	18.5	9.5	57.5
29 Jan 82	.303	.35	.473	6.0	3.0	18.7
12-15 Mar 82	.80	.95	4.383	46.0	10.9	65.7
4-5 May 82	.310	.35	1.108	24.2	7.1	42.9
23 July 82	.240	.28	1.497	33.2	12.1	74.9
24 July 82	.330	.38	1.998	38.6	11.8	72.7
8-9 Nov 82	.380	.40	.426	2.2	2.1	13.5
16-17 Nov 82	.330	.45	1.723	28.6	10.3	62.7
30 Nov-2 Dec 82	.790	.90	7.699	62.2	19.2	116.9
9-10 Dec 82	.770	.78	6.183	28.1	15.8	96.4
23 Dec 82	.230	.26	1.776	28.6	15.2	92.7
30-31 Dec 82	.190	.25	.271	.8	2.6	17.1
19-20 Jan 83	.35	.42	1.614	1.0	9.1	55.3
2-3 Feb 83	.24	.27	.209	.9	1.7	10.5
3-4 Mar 83	.98	1.20	9.788	32.2	19.7	119.9
18-19 Mar 83	.53	.70	2.383	8.4	8.9	54.0
13 Sept 83	.30	.36	.842	16.5	6.0	33.7
28 Sept 83	.33	.40	3.003	52.3	18.0	109.2
29-30 Sept 83	1.85	2.00	16.625	62.2	18.0	107.8
1-2 Oct 83	3.94	4.08	7.699	91.6	4.0	23.4
3-4 Nov 83	.64	.68	3.128	17.0	10.0	58.7
21 Nov 83	.78	.79	3.234	15.1	8.0	49.8
2 Dec 83	.31	.32	.370	1.8	2.2	14.3
26 Dec 83	.51	.67	3.427	42.7	13.1	80.6

# of events = 126

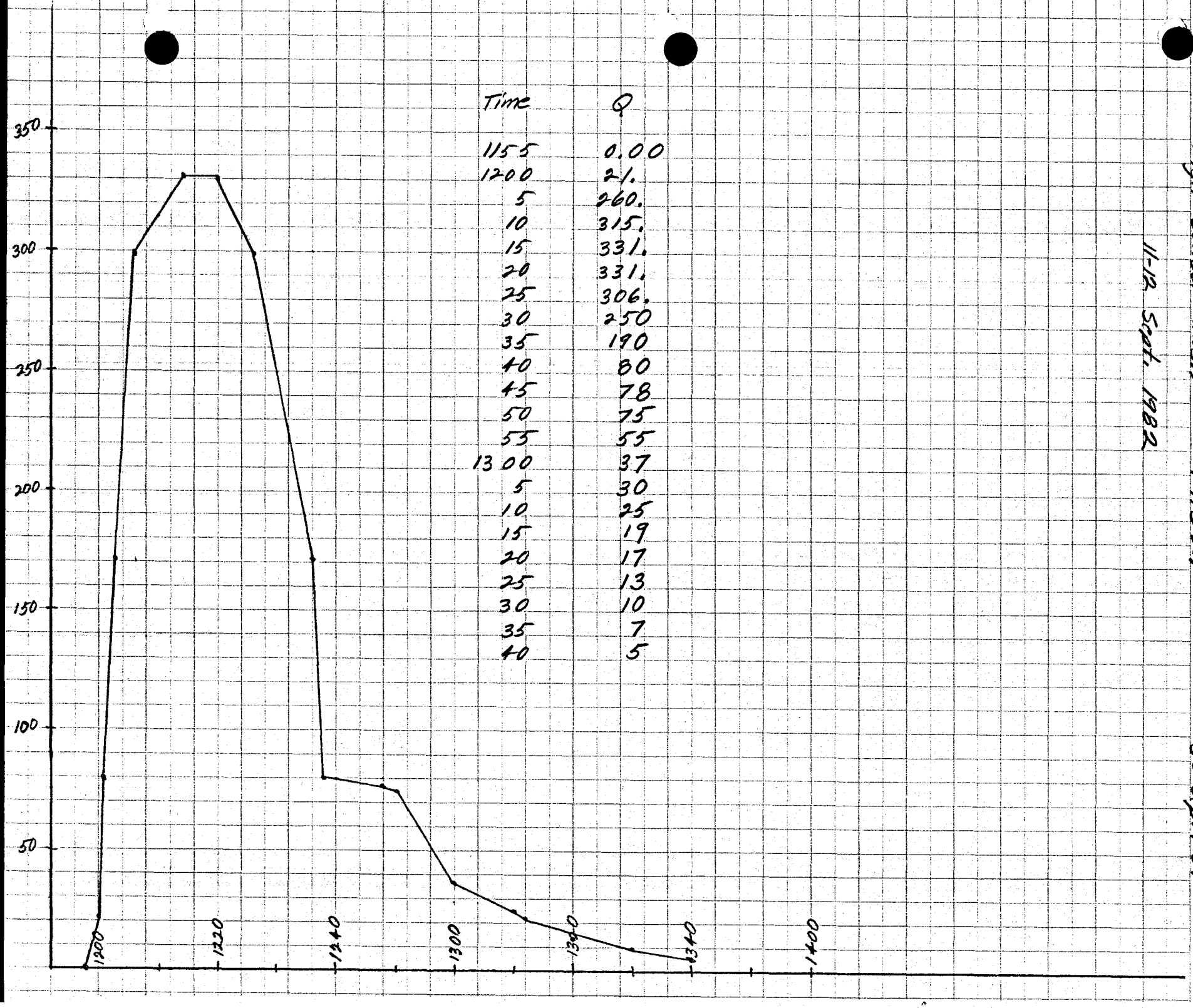
Mean = 65.1 acres = 11.3 %

Std. Dev. = 29.9


High School Wash
29 Sept 87
25310
K = 20/205 = .098
R = .43 hr
13 Aug 80
K = 18/500 = .036
R = .30 hr
Sept 82
K = 4.4/500 = .009
R = .21 hr
partial area rainfall
25 July 82
11-12 Sept 82
1200
1300
1400
400
500
600
13 Aug 80
700
800
1500
25 July 82
1600
Semi-Logarithmic 3 Cycles x 10 To The Inch

High School Marsh THS 2.

11-12 Sept. 1982 30 Sept 87



Time	Q
1155	0.00
1200	21.
5	260.
10	315.
15	331.
20	331.
25	306.
30	250
35	190
40	80
45	78
50	75
55	55
1300	37
5	30
10	25
15	19
20	17
25	13
30	10
35	7
40	5

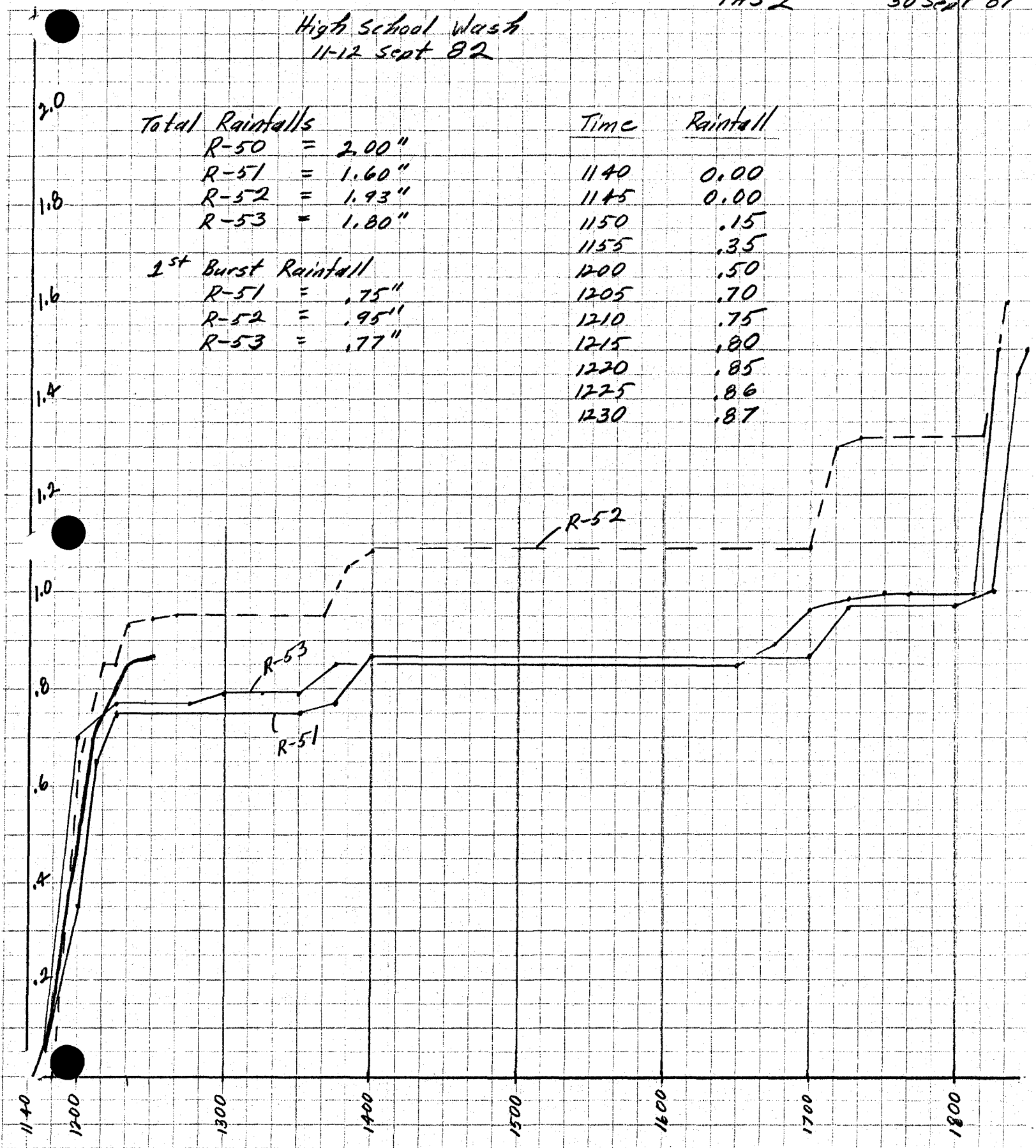
THS 2 30 Sept 87

High School Wash
11-12 Sept 82

Total Rainfalls
R-50 = 2.00"
R-51 = 1.60"
R-52 = 1.93"
R-53 = 1.80"

1st Burst Rainfall
R-51 = .75"
R-52 = .95"
R-53 = .77"

Time	Rainfall
1140	0.00
1145	0.00
1150	.15
1155	.35
1200	.50
1205	.70
1210	.75
1215	.80
1220	.85
1225	.86
1230	.87



Flood Reconstitution for Tucson High School Wash THS 1

Storm Event 13 Aug 80

Runoff: depth = .67 inches, Q_p = 360 / 270 cfs at t_p = .83 / 1.33 hours

$R_{recession}$ = .43 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
576	11.3	1.9	5	D		329	1.0	.10	.68	.39	.46	Ø1	multiple peak hg.
"	"	"	10	D		314	1.0	.17	.54	.39	.40	Ø2	
"	"	"	5	U-6		327	1.08	.12	.73	.35	.44	Ø3	
"	"	"	2	D		321	1.0	.06	.57	.49	.56	Ø4	
"	"	"	"	U-1		323	1.03	.17	.55	.48	.57	Ø5	← best

Flood Reconstitution for Tucson High School Wash THS 2

Storm Event 11-12 Sept 82

Runoff: depth = .38 inches, Q_p = 331 cfs at t_p = .50 hours

$R_{recession}$ = .30 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
576	11.3	.87	5	U-4		336	.50	.20	.35	.40	.35	Ø1	
"	"	"	"	U-1		342	.50	.28	.32	.45	.23	Ø2	← best
"	"	"	"	U-6		322	.50	.13	.39	.41	.33	Ø3	

Flood Reconstitution by HEC-1

Output THS2.Φ2

```
1                                    ****
                FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
          U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                    ****


          THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3


1                                  HEC-1 INPUT                                                  PAGE  1

      LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

        1         ID   HIGH SCHOOL WASH                                                  watershed
        2         ID   UNIV OF TUCSON URBAN HYDROLOGY PROGRAM
        3         ID   STORM EVENT 11 SEPTEMBER 1982                                    event
        4         ID   UNIT-HYDROGRAPH OPTIMIZATION
*** FREE ***                 computation interval, in minutes
        5         IT      5 11SEP82    1145      60
        6         IO      0       2
        7         OU

        8         KK   THS2
        9         PB    .87 ← rainfall depth
       10         PI    .15     .2     .15     .2     .05     .05     .05     .01     .01   rainfall distribution
       11         QO      0      0       0     21     260     315     331     331     306     250 } recorded hydrograph
       12         QO    190     80      78     75      55      37      30      25      19      17 }
       13         QO     13     10       7      5                                                }
       14         BA    .90 ← drainage area, in sq. miles
       15         UA      0     10      45     75      84      90      94      96      98      99 } Time-Area relation
       16         UA    100                                                                        } U-1
       17         UC    -.5    -.4 ← initial values of Tc & R
       18         LU    -.4    -.2   11.3 — effective impervious area
       19         ZZ    initial values of STRTL & CNSTL
1                                    ****
                FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
          U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                    ****
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                    HIGH SCHOOL WASH
                    UNIV OF TUCSON URBAN HYDROLOGY PROGRAM
                    STORM EVENT 11 SEPTEMBER 1982
                    UNIT-HYDROGRAPH OPTIMIZATION

 6 IO        OUTPUT CONTROL VARIABLES
                  IPRNT          0  PRINT CONTROL
                  IPLOT          2  PLOT CONTROL
                  QSCAL         0.  HYDROGRAPH PLOT SCALE

  IT         HYDROGRAPH TIME DATA
                   NMIN          5  MINUTES IN COMPUTATION INTERVAL
                  IDATE    11SEP82  STARTING DATE
                  ITIME       1145  STARTING TIME
                     NQ         60  NUMBER OF HYDROGRAPH ORDINATES
                 NDDATE    11SEP82  ENDING DATE
                 NDTIME       1640  ENDING TIME

              COMPUTATION INTERVAL     .08 HOURS
                   TOTAL TIME BASE    4.92 HOURS

      ENGLISH UNITS

  OU         OPTIMIZATION OF UNITGRAPH AND LOSS RATE PARAMETERS
                  IFORD          1  FIRST ORDINATE OF OPTIMIZATION REGION
                  ILORD         60  LAST ORDINATE OF OPTIMIZATION REGION


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***


          **************
          *            *
 8 KK     *     THS2   *
          *            *
          **************

            SUBBASIN RUNOFF DATA

 14 BA        SUBBASIN CHARACTERISTICS
                  TAREA        .90  SUBBASIN AREA

              PRECIPITATION DATA

  9 PB            STORM        .87  BASIN TOTAL PRECIPITATION

 10 PI          INCREMENTAL PRECIPITATION PATTERN
                  .15      .20      .15      .20      .05      .05      .05      .01      .01

 18 LU        UNIFORM LOSS RATE
                  STRTL       -.40  INITIAL LOSS
                  CNSTL       -.20  UNIFORM LOSS RATE
                  RTIMP      11.30  PERCENT IMPERVIOUS AREA

 17 UC        CLARK UNITGRAPH
                    TC       -.50  TIME OF CONCENTRATION
                     R       -.40  STORAGE COEFFICIENT

 14 UA        ACCUMULATED-AREA VS. TIME,  11 ORDINATES
                   .0     10.0     45.0     75.0     84.0     90.0     94.0     96.0     98.0     99.0
                100.0

                                                                                                  ***
```

INITIAL ESTIMATES FOR OPTIMIZATION VARIABLES

TC+R	R/(TC+R)	STRTL	CNSTL
.90	.44	.40	.20

INTERMEDIATE VALUES OF OPTIMIZATION VARIABLES
(*INDICATES CHANGE FROM PREVIOUS VALUE)
(+INDICATES VARIABLE WAS NOT CHANGED)

OBJECTIVE FUNCTION	TC+R	R/(TC+R)	STRTL	CNSTL
VOL. ADJ.	.900	.444	.451*	.226*
23.1	.600*	.444	.451	.226
19.3	.600	.527*	.451	.226
19.3	.600	.527	.448*	.226
19.3	.600	.527	.448	.227*
19.3	.599*	.527	.448	.227
19.2	.599	.531*	.448	.227
19.2	.599	.531	.447*	.227
19.2	.599	.531	.447	.226*
19.2	.600*	.531	.447	.226
19.2	.600	.535*	.447	.226
19.2	.600	.535	.446*	.226
19.2	.600	.535	.446	.225*
19.2	.601*	.535	.446	.225
19.2	.601	.536*	.446	.225
19.2	.601	.536	.446*	.225
19.2	.601	.536	.446	.225*
19.2	.601+	.536	.446	.225
VOL. ADJ.	.601	.536	.451*	.227*

```
*********************************************
*                                           *
*            OPTIMIZATION RESULTS           *
*                                           *
*********************************************
*                                           *
*   CLARK UNITGRAPH PARAMETERS              *
*        TC      .28                        *
*        R       .32                        *
*                                           *
*   SNYDER STANDARD UNITGRAPH PARAMETERS    *
*        TP      .15                        *
*        CP      .34                        *
*                                           *
*   LAG FROM CENTER OF MASS OF EXCESS       *
*   TO CENTER OF MASS OF UNITGRAPH     .38  *
*                                           *
*   UNITGRAPH PEAK     1210.                *
*   TIME OF PEAK        .17                 *
*                                           *
*********************************************
*                                           *
*                                           *
*   UNIFORM LOSS RATE PARAMETERS            *
*      STRTL     .45                        *
*      CNSTL     .23                        *
*                                           *
*********************************************
```

Parameter Optimization

COMPARISON OF COMPUTED AND OBSERVED HYDROGRAPHS

STATISTICS BASED ON OPTIMIZATION REGION
(ORDINATES 1 THROUGH 60)

	SUM OF FLOWS	EQUIV DEPTH	MEAN FLOW	TIME TO CENTER OF MASS	LAG C.M. TO C.M.	PEAK FLOW	TIME OF PEAK
PRECIPITATION EXCESS		.380		.43			
COMPUTED HYDROGRAPH	2635.	.378	44.	.77	.34	342.	.50
OBSERVED HYDROGRAPH	2635.	.378	44.	.95	.52	331.	.50
DIFFERENCE	0.	.000	0.	-.18	-.18	11.	.00
PERCENT DIFFERENCE	-.01				-34.67	3.43	

STANDARD ERROR 15. AVERAGE ABSOLUTE ERROR 9.
OBJECTIVE FUNCTION 19. AVERAGE PERCENT ABSOLUTE ERROR 70.25

UNIT HYDROGRAPH — used to generate the S-graph

22 END-OF-PERIOD ORDINATES

597.	1210.	1127.	917.	715.	551.	425.	327.	252.	194.
150.	115.	89.	69.	53.	41.	31.	24.	19.	14.
11.	9.								

HYDROGRAPH AT STATION THS2

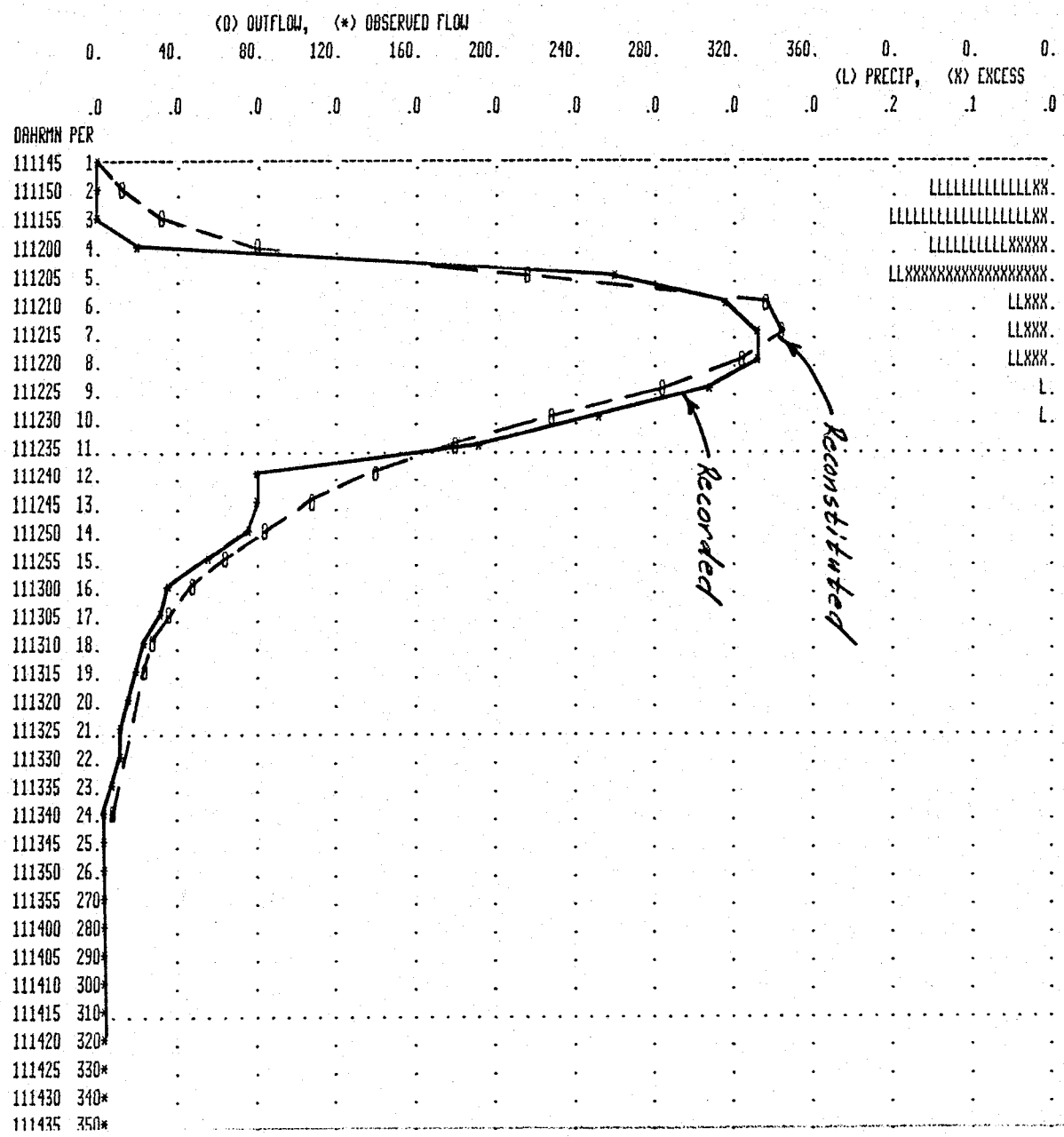
DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	OBS Q	DA MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	OBS Q
11 SEP 1145	1	.00	.00	.00	0.	0.	11 SEP 1415	31	.00	.00	.00	0.	5.
11 SEP 1150	2	.15	.13	.02	10.	0.	11 SEP 1420	32	.00	.00	.00	0.	5.
11 SEP 1155	3	.20	.18	.02	34.	0.	11 SEP 1425	33	.00	.00	.00	0.	5.
11 SEP 1200	4	.15	.10	.05	79.	21.	11 SEP 1430	34	.00	.00	.00	0.	5.
11 SEP 1205	5	.20	.02	.18	217.	260.	11 SEP 1435	35	.00	.00	.00	0.	5.
11 SEP 1210	6	.05	.02	.03	336.	315.	11 SEP 1440	36	.00	.00	.00	0.	5.
11 SEP 1215	7	.05	.02	.03	342	331.	11 SEP 1445	37	.00	.00	.00	0.	5.
11 SEP 1220	8	.05	.02	.03	324.	331	11 SEP 1450	38	.00	.00	.00	0.	5.
11 SEP 1225	9	.01	.01	.00	285.	306.	11 SEP 1455	39	.00	.00	.00	0.	5.
11 SEP 1230	10	.01	.01	.00	230.	250.	11 SEP 1500	40	.00	.00	.00	0.	5.
11 SEP 1235	11	.00	.00	.00	180.	190.	11 SEP 1505	41	.00	.00	.00	0.	5.
11 SEP 1240	12	.00	.00	.00	139.	80.	11 SEP 1510	42	.00	.00	.00	0.	5.
11 SEP 1245	13	.00	.00	.00	107.	78.	11 SEP 1515	43	.00	.00	.00	0.	5.
11 SEP 1250	14	.00	.00	.00	83.	75.	11 SEP 1520	44	.00	.00	.00	0.	5.
11 SEP 1255	15	.00	.00	.00	64.	55.	11 SEP 1525	45	.00	.00	.00	0.	5.
11 SEP 1300	16	.00	.00	.00	49.	37.	11 SEP 1530	46	.00	.00	.00	0.	5.
11 SEP 1305	17	.00	.00	.00	38.	30.	11 SEP 1535	47	.00	.00	.00	0.	5.
11 SEP 1310	18	.00	.00	.00	29.	25.	11 SEP 1540	48	.00	.00	.00	0.	5.
11 SEP 1315	19	.00	.00	.00	23.	19.	11 SEP 1545	49	.00	.00	.00	0.	5.
11 SEP 1320	20	.00	.00	.00	17.	17.	11 SEP 1550	50	.00	.00	.00	0.	5.
11 SEP 1325	21	.00	.00	.00	13.	13.	11 SEP 1555	51	.00	.00	.00	0.	5.
11 SEP 1330	22	.00	.00	.00	10.	10.	11 SEP 1600	52	.00	.00	.00	0.	5.
11 SEP 1335	23	.00	.00	.00	8.	7.	11 SEP 1605	53	.00	.00	.00	0.	5.
11 SEP 1340	24	.00	.00	.00	6.	5.	11 SEP 1610	54	.00	.00	.00	0.	5.
11 SEP 1345	25	.00	.00	.00	4.	5.	11 SEP 1615	55	.00	.00	.00	0.	5.
11 SEP 1350	26	.00	.00	.00	3.	5.	11 SEP 1620	56	.00	.00	.00	0.	5.
11 SEP 1355	27	.00	.00	.00	1.	5.	11 SEP 1625	57	.00	.00	.00	0.	5.
11 SEP 1400	28	.00	.00	.00	1.	5.	11 SEP 1630	58	.00	.00	.00	0.	5.
11 SEP 1405	29	.00	.00	.00	0.	5.	11 SEP 1635	59	.00	.00	.00	0.	5.
11 SEP 1410	30	.00	.00	.00	0.	5.	11 SEP 1640	60	.00	.00	.00	0.	5.

TOTAL RAINFALL = .87, TOTAL LOSS = .49, TOTAL EXCESS = .38

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	4.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 342.	.50		45.	45.	45.	45.
		(INCHES)	.378	.378	.378	.378
		(AC-FT)	18.	18.	18.	18.

CUMULATIVE AREA = .90 SQ MI

1 STATION THS2



(-) LIMITS OF OPTIMIZATION

1

1

** STATION THS2 ** DRAINAGE AREA = .90

..DATE...		.....PERCENT ERROR.....				..... O P T I M I Z A T I O N R E S U L T S								
DA	MON	YR	AVG	VOL	LAG	PEAK	TC	R	TC+R	R/(TC+R)	TP	CP	QP	STRTL	CNSTL
11	SEP	82	70.3	.0	-34.7	3.4	.28	.32	.60	.54	.15	.34	1462.	.45	.23

*** NORMAL END OF HEC-1 ***

Summary of Flood Reconstitutions

Watershed Code (1)	Area acres (2)	Eff. Imp. Area % (3)	Storm Event (4)	Rain in. (5)	Runoff in. (6)	Q_p Obs. cfs (7)	Q_p Comp. cfs (8)	t_p Obs. hr. (9)	t_p Comp. hr. (10)	Lag hr (11)	T_c hr. (12)	R hr. (13)	$R_{rec.}$ hr. (14)	Comp. Int. min. (15)	Time-Area (16)	STRTL in. (17)	CNSTL in/hr (18)	Output File (19)	Comment (20)
AVDØ1	33.3	16.4	1 July 81	.50	.18	24	24	.25	.25	.09	.02	.11	.15	1	D	.33	.27	Ø3	
AVDØ2	"	"	1 Aug 82	1.12	.39	34	36	.33	.40	.13	.03	.17	.19	2	D	.56	1.32	Ø2	
AAA1	79.4	16.3	12 Aug 82	.63	.24	37	38	.40	.35	.29	.17	.31	.29	1	U-3	.44	.11	Ø5	
AAA2	"	"	25 June 81	.57	.20	49	50	.40	.37	.16	.03	.20	.20	2	D/U-3	.20	.35	Ø01/Ø2	very short T_c
ATR1	87.0	9.6	29 July 83	.57	.13	26	29	.40	.38	.12	.02	.16	.26	1	U-1	.33	.49	Ø12	very short T_c
ALA1	57.6	0	6 Sept 80	1.23	.26	37	34	.58	.58	.15	.05	.19	.19	1	U-8	.69	.47	Ø4	
ALA2	"	"	8 Sept 80	.73	.14	15	16	.58	.62	.27	.26	.29	.28	1	U-8	.55	.26	Ø2	
ALA3	"	"	7 July 81	.99	.20	18	20	.58	.43	.39	.02	.55	.31	1	U-8	.59	.49	Ø2	high intensity for 15-min.
ACA1	57.0	0	6 Sept 80	1.00	.40	80	70	.42	.43	.15	.07	.14	.22	1	N-1	.36	.35	Ø4	
ACA2	"	"	7 July 81	.98	.23	49	44	.42	.45	.34	.05	.19	.23	1	N-1	.62	.15	Ø3	
ANCA1	134.4	0	14 Aug 80	3.69	.43	131	121	1.58	1.53	.31	.08	.38	.34	2	N-1	2.15	1.50	Ø4	
ANCA2	"	"	7 July 81	.98	.37	134	120	.42	.43	.27	.04	.36	.36	2	N-1	.36	.15	Ø5	

Summary of Flood Reconstitutions

Watershed Code (1)	Area acres (2)	Eff. Imp. Area % (3)	Storm Event (4)	Rain in. (5)	Runoff in. (6)	Q_p Obs. cfs (7)	Q_p Comp. cfs (8)	t_p Obs. hr. (9)	t_p Comp. hr. (10)	Lag hr. (11)	T_c hr. (12)	R hr. (13)	$R_{rec.}$ hr. (14)	Comp. Int. min. (15)	Time-Area (16)	STRTL in. (17)	CNSTL in/hr (18)	Output File (19)	Comment (20)
D116 1	170.0	13.3	3 June 81	.93	.36	123	131	.50	.50	.21	.08	.27	.18	2	U-1	.61	.23	Φ3	
D116 2	"	"	22 Aug 81	.33	.05	28	—	.27	—	—	—	—	.27	—	—	—	—	—	this event cannot be reconstituted
DVI 1	77.0	82	20 April 80	.54	.47	77	70	.58	.57	.20	.14	.18	.10	2	D	.74	.15	Φ4	
DCD 1	96.0	90	1 Aug 76	1.97	1.78	285	253	.67	.63	.24	.18	.21	.20	2	D	1.62	.46	Φ2	
DGC 1	441.6	15.4	25 July 76	.86	.30	137	129	.75	.75	.63	.70	.35	.32	5	D	.61	.04	Φ3	
DSC 1	185.6	24.0	30 July 74	1.38	.52	251	255	.42	.43	.14	.11	.16	.16	5	U-1	.74	1.33	Φ4	
DSC 2	"	"	1 Aug 76	1.30	.42	196	219	.42	.40	.15	.27	.11	.18	2	U-1	.95	.55	Φ2	

Summary of Flood Reconstitutions

Watershed Code (1)	Area acres (2)	Eff. Imp. Area % (3)	Storm Event (4)	Rain in. (5)	Runoff in. (6)	Q_p Obs. cfs (7)	Q_p Comp. cfs (8)	t_p Obs. hr. (9)	t_p Comp. hr. (10)	Lag hr. (11)	T_c hr. (12)	R hr. (13)	$R_{rec.}$ hr. (14)	Comp. Int. min. (15)	Time-Area (16)	STRTL in. (17)	CNSTL in/hr (18)	Output File (19)	Comment (20)
THS1	576	11.3	13 Aug 80	1.9	.67	360	323	.83	1.03	.42	.17	.55	.43	2	U-1	.48	.57	Ø5	multiple peak hg.
THS2	"	"	11-12 Sept 82	.87	.38	331	342	.50	.50	.30	.28	.32	.30	5	U-1	.45	.23	Ø2	
TAR1	2040	10.9	1 Sept 71	1.45	.41	1430	1265	1.25	1.25	.89	1.48	.14	.39	5	U-7	.96	.47	Ø7	estimated peak
TAR2	"	"	23 Aug 82	1.10	.12	360	357	.92	.92	1.41	1.03	.26	.35	5	U-7	1.00	.56	Ø3	
TAR3	"	"	11 Sept 82	1.00	.25	461	442	1.50	1.50	.84	.80	.58	.43	5	U-7	.87	.46	Ø4	
TAR4	"	"	11 Sept 82	1.30	.54	867	824	.83	.83	.82	.71	.61	.54	5	U-7	.69	.38	Ø3	1" antecedent rain
TRR1	1472	17.0	11-12 Sept 82	.75	.41	515	504	2.00	1.92	1.10	1.46	.51	.43	5	U-5	.24	.05	Ø7	.6" antecedent rain
TRR2	"	"	2 Aug 82	.95	.30	350	341	2.50	2.50	.89	1.07	.48	.61	10	U-5	.57	.52	Ø4	
TAT1	3181	3.0	26 Sept 84	1.40	.27	178	200	5.00	4.75	3.42	2.36	3.18	2.10	15	D	.17	.33	Ø3	
TAT2	"	"	11 Sept 82	1.42	.35	325	392	1.75	2.00	—	.26	2.71	1.80	15	D	.48	1.06	Ø1	questionable T_c
TAT3	"	"	25-26 Sept 76	1.70	.51	340	296	2.25	4.00	—	2.74	3.48	1.83	15	D	.10	.96	Ø1	complex hg.

Summary of Flood Reconstitutions

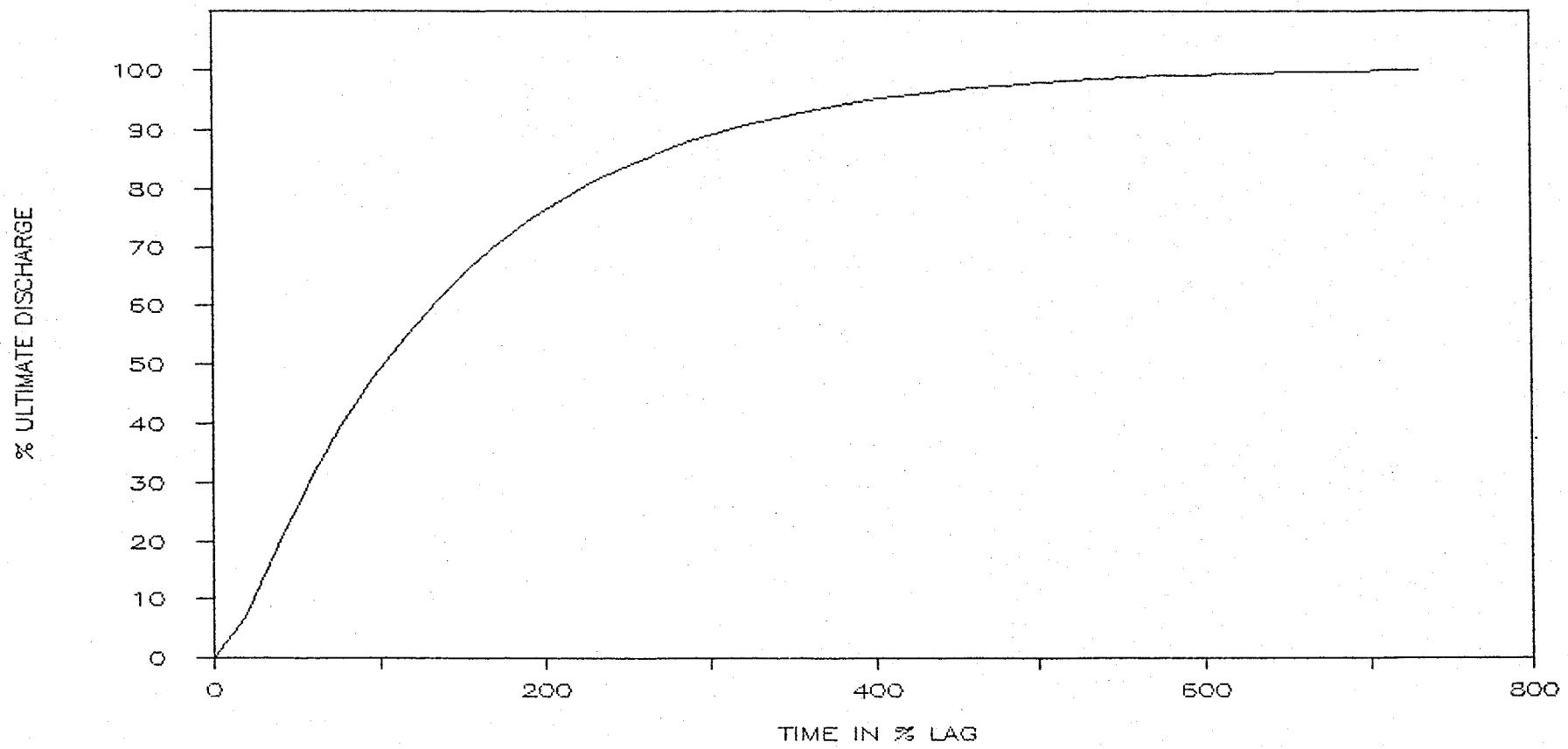
Watershed Code (1)	Area acres (2)	Eff. Imp. Area % (3)	Storm Event (4)	Rain in. (5)	Runoff in. (6)	Q_p Obs. cfs (7)	Q_p Comp. cfs (8)	t_p Obs. hr. (9)	t_p Comp. hr. (10)	Lag hr. (11)	T_c hr. (12)	R hr. (13)	$R_{rec.}$ hr. (14)	Comp. Int. min. (15)	Time-Area (16)	STRTL in. (17)	CNSTL in/hr (18)	Output File (19)	Comment (20)
4-1	560	0	10 Aug 71	1.25	.36	401	373	1.17	1.13	.47	.58	.22	.18	2	D	.70	.40	Ø1	
4-2	"	"	17 Aug 61	1.80	.44	355	358	.90	.83	.55	.61	.32	.17	2	D	1.13	.76	Ø2	
8-1	3830	0	6 Sept 76	.75	.15	588	567	1.00	.80	.71	.32	.79	.52-.78	6	D	.43	.41	Ø6	invalid reconstitutio. long watershed
8-2	"	"	10 Aug 71	1.62	.14	1280	1263	1.00	1.00	.30	.18	.29	.23	5	D	1.29	1.21	Ø1	non-uniform rain
11-1	2035	0	13 Sept 75	.90	.21	698	722	.63	.60	.45	.52	.33	.18	2	U-3	.50	.50	Ø4	flat peak
11-2	"	"	22 July 64	1.80	.97	4420	4188	.83	.83	.37	.46	.16	.16	5	D	.72	.56	Ø3	
15-1	5912	0	6 Sept 76	.70	.08	543	510	1.40	1.40	1.07	2.51	.36	.36	4	N-4	.57	.49	Ø2	
103-1	8.3	0	10 Aug 71	1.04	.48	19	19	.23	.23	.082	.02	.11	.15	1	D	.17	1.08	Ø1	
103-2	"	"	8 Sept 70	1.41	.67	17	17	.30	.32	.075	.02	.09	.16	1	D	.09	1.12	Ø1	
111-1	143	0	19 Aug 63	1.19	.47	264	208	.43	.47	.045	.03	.03	.11	2	D	.64	.33	Ø1	
111-2	"	"	11 Sept 64	1.95	.83	284	273	.73	.73	.21	.16	.18	.12	2	D	.93	.30	Ø1	
111-3	"	"	4 Sept 65	.175	.22	88	90	.43	.40	.20	.18	.14	.13	2	D	.41	.27	Ø1	

Summary of Flood Reconstitutions

Watershed Code (1)	Area acres (2)	Eff. Imp. Area % (3)	Storm Event (4)	Rain in. (5)	Runoff in. (6)	Q_p Obs. cfs (7)	Q_p Comp. cfs (8)	t_p Obs. hr. (9)	t_p Comp. hr. (10)	Lag hr. (11)	T_c hr. (12)	R hr. (13)	$R_{rec.}$ hr. (14)	Comp. Int. min. (15)	Time-Area (16)	STRTL in. (17)	CNSTL in/hr (18)	Output File (19)	Comment (20)
WCU 1	441.6	0	12 June 67	1.04	.33	168	134	2.08	2.25	1.53	1.46	.43	.66	5	N-3	.62	.07	Φ04	
WCU 2	"	"	10 June 69	1.60	.92	275	274	1.08	1.17	.91	.49	.73	.73	5	N-3	.48	.11	Φ02	
WC 1	1184.0	0	10 June 69	1.28	.51	421	429	1.42	1.50	1.06	.86	.64	.87	5	N-1	.56	.13	Φ02	
WC 2	"	"	5 June 72	2.34	1.21	1260	1233	1.42	1.33	.79	.45	.66	.63	5	N-1	.80	.12	Φ03	
WDH1	979.2	0	3 June 72	1.22	1.12	2040	1693	.83	.83	.80	.74	.34	.44	5	N-1	.08	.06	Φ02	
WET1	3482.	0	10 June 65	1.56	.63	4450	4031	1.58	1.58	.31	.39	.12	.41	5	N-6	.88	.12	Φ4	questionable rain distribution
WD1	454.4	0	24 June 65	.91	.50	493	499	.50	.50	.36	.47	.09	.16	5	comp.	.27	.07	Φ02	
WHD1	2124.8	0	16 July 69	1.39	.34	1670	1733	.50	.50	.32	.18	.26	.34	5	D	.97	.12	Φ01	very short T_c
WMB 1	1926.4	0	28 June 73	1.02	.35	679	623	1.17	1.17	.89	1.04	.43	.39	5	comp.	.64	.06	Φ02	

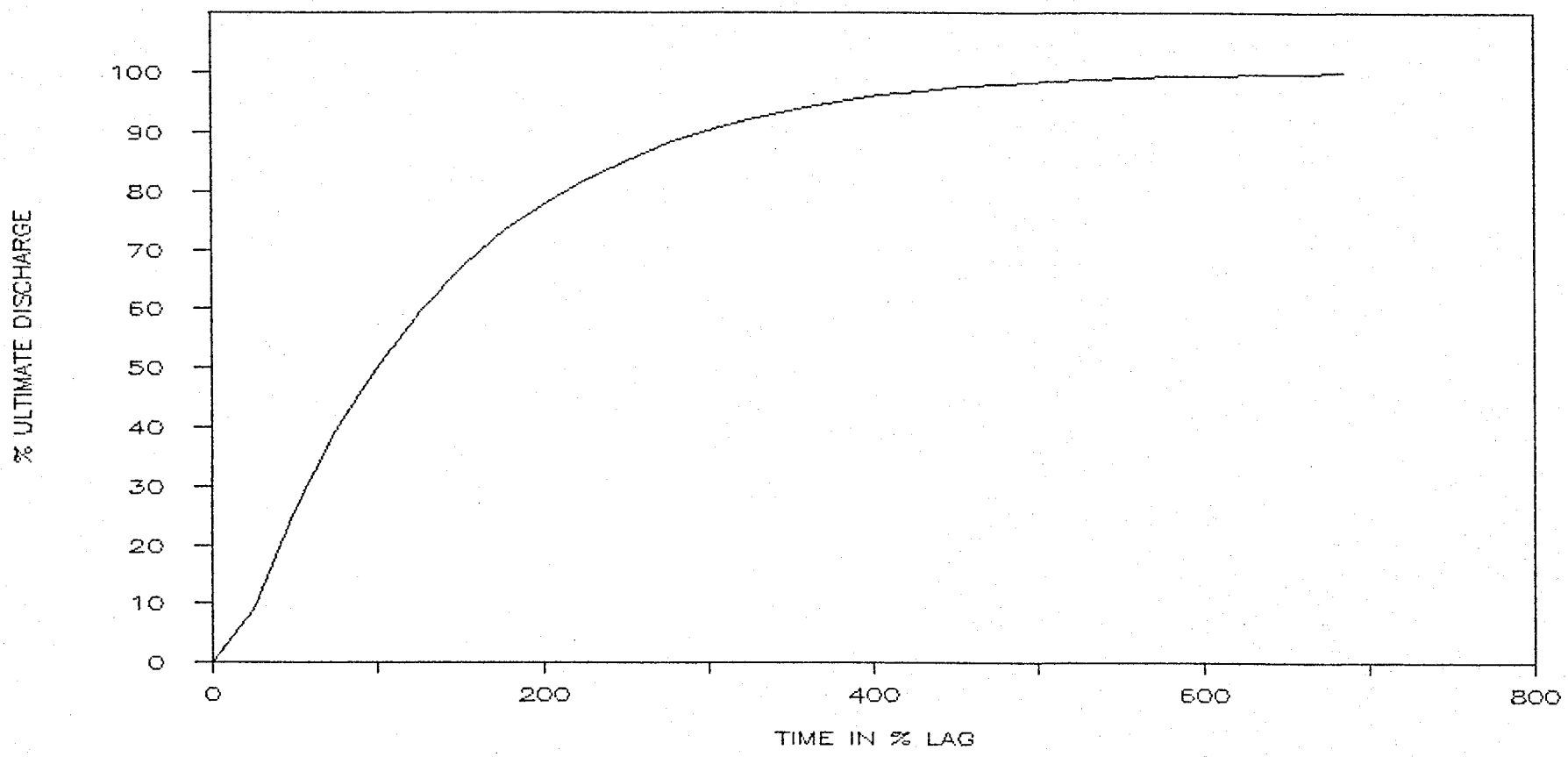
AVD01.03 VILLA DEL OSO DRAIN

1 JULY 1981



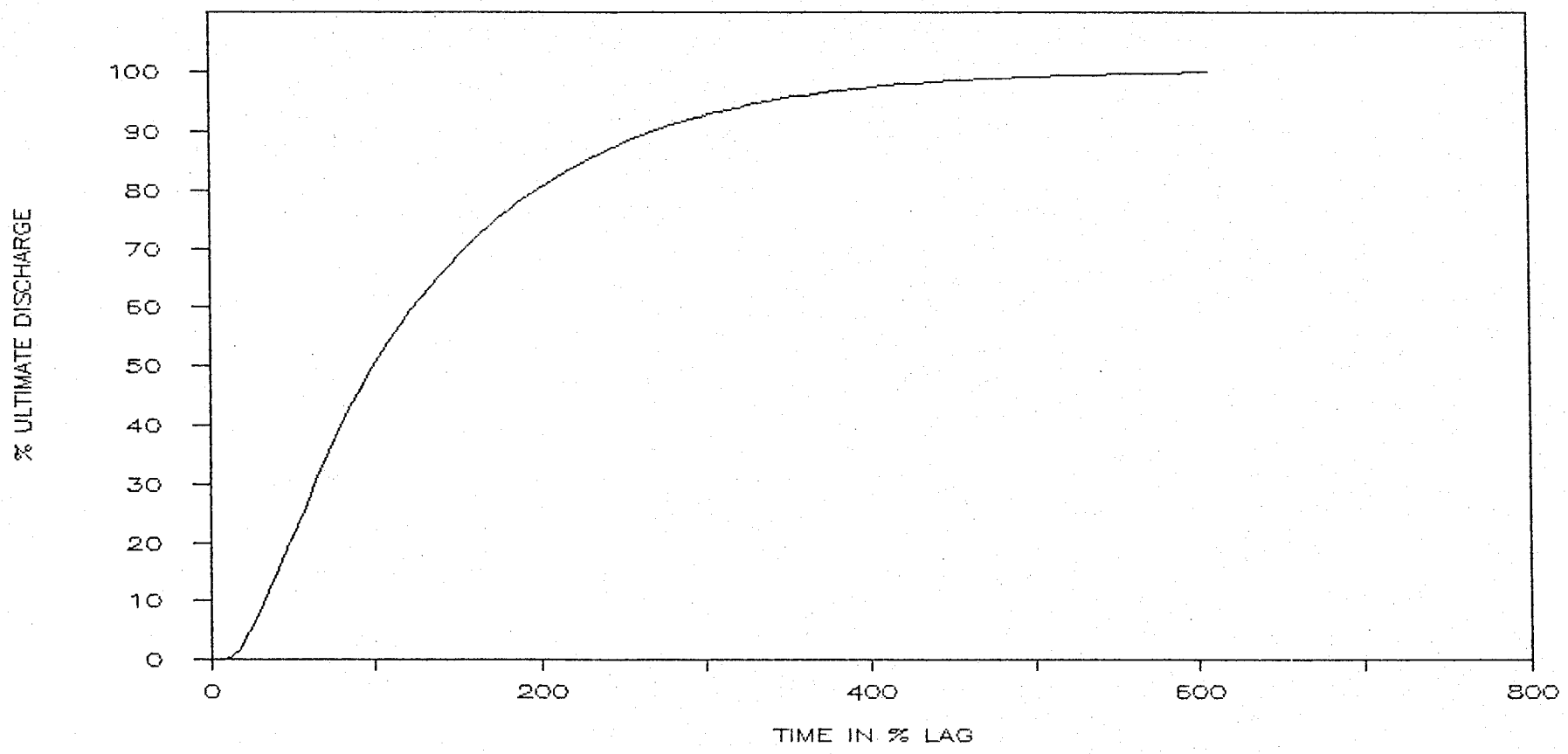
AVD02.02 VILLA DEL OSO DRAIN

1 AUGUST 1982



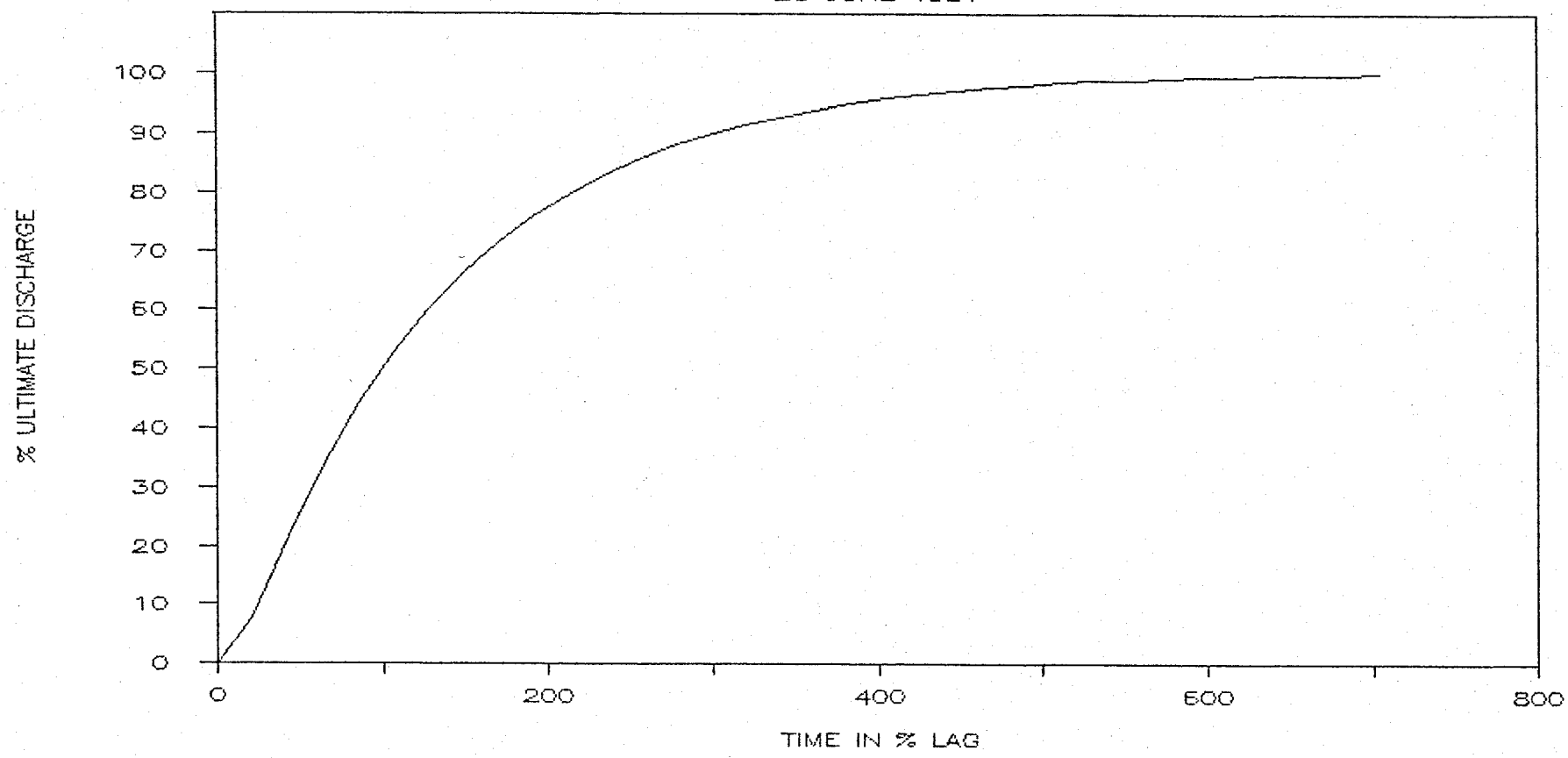
AAA1.05 ACADEMY ACRES DRAIN

12 AUGUST 1982



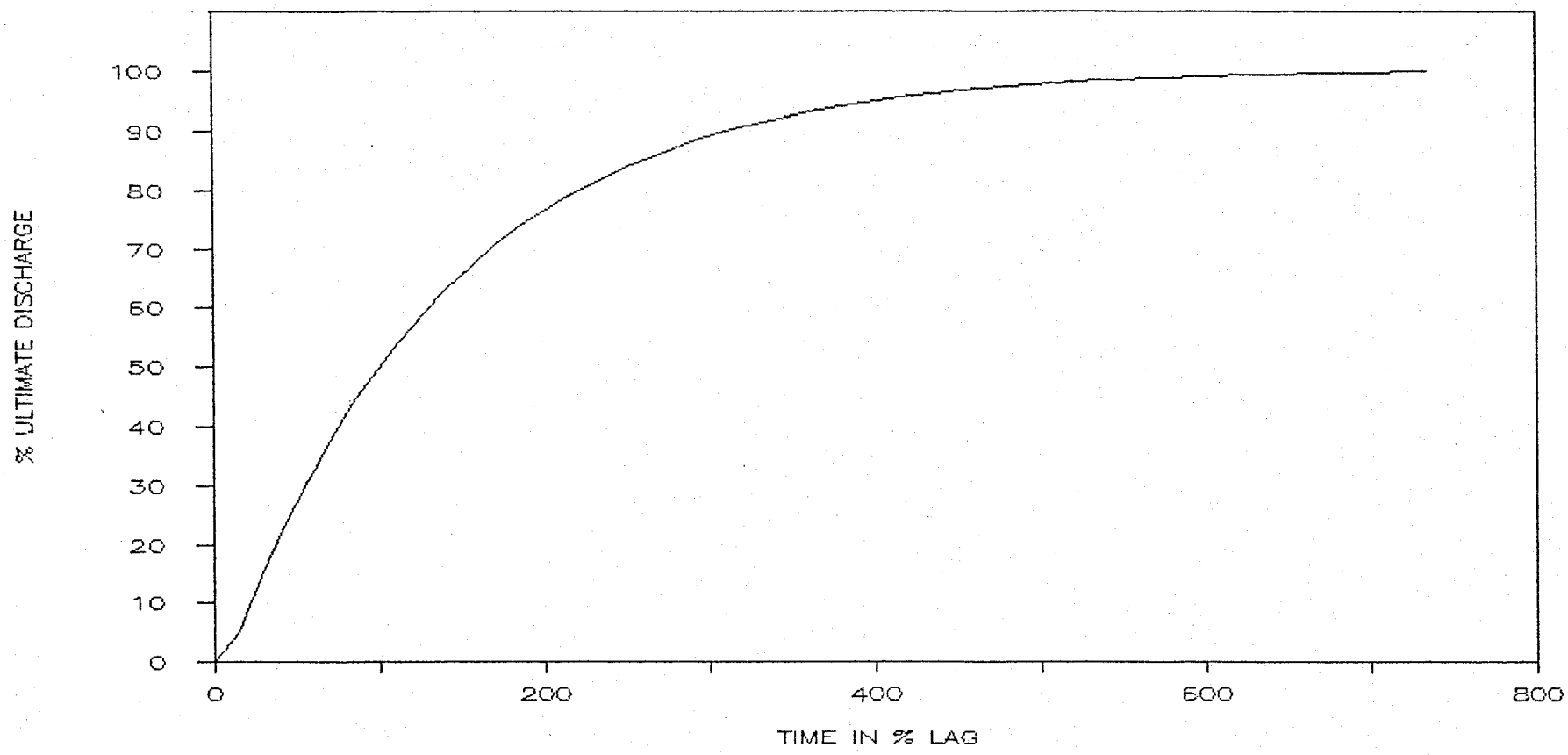
AAA2.001 ACADEMY ACRES DRAIN

25 JUNE 1981



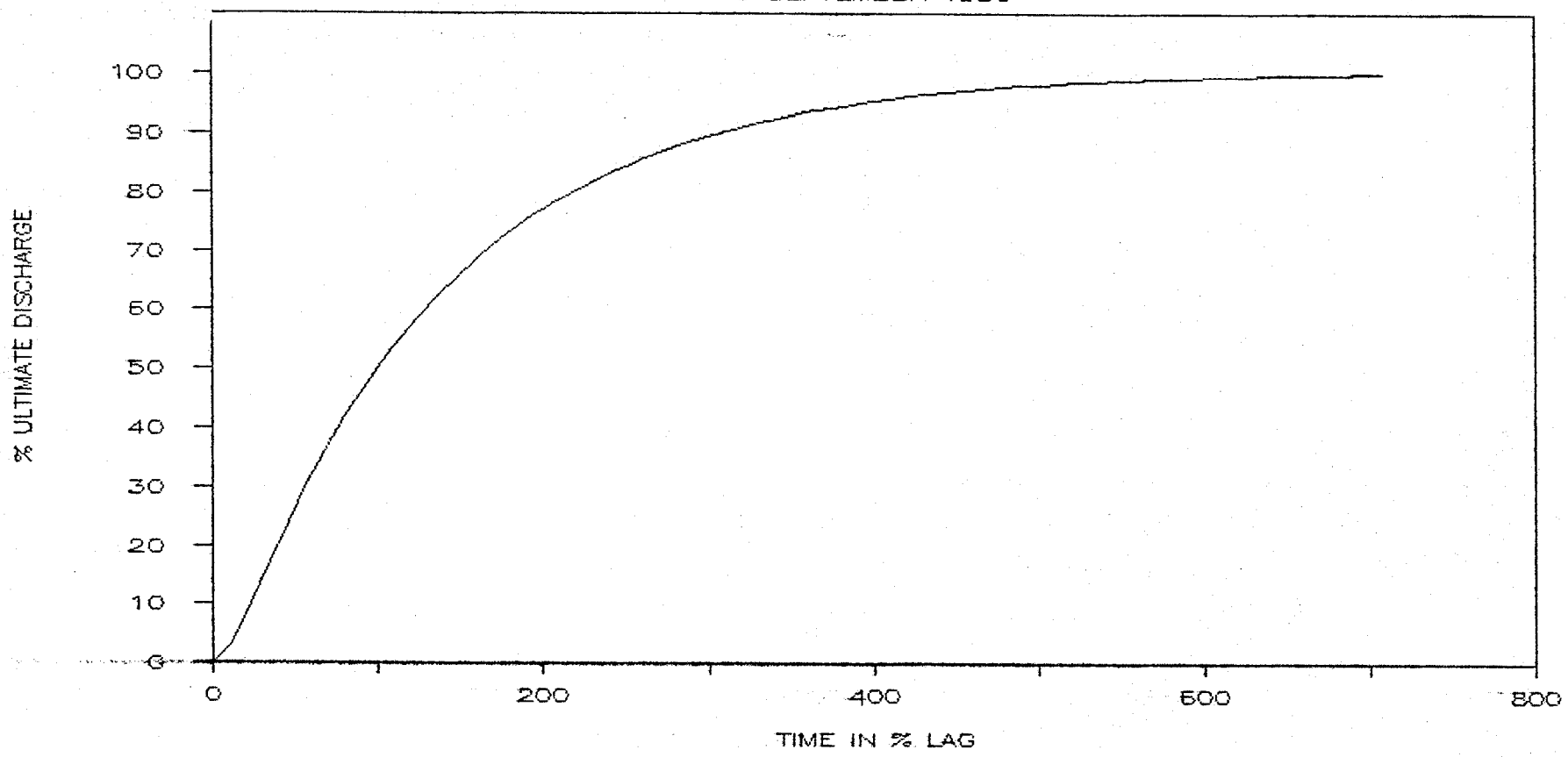
ATR1.012 TAYLOR RANCH DRAIN

29 JULY 1983



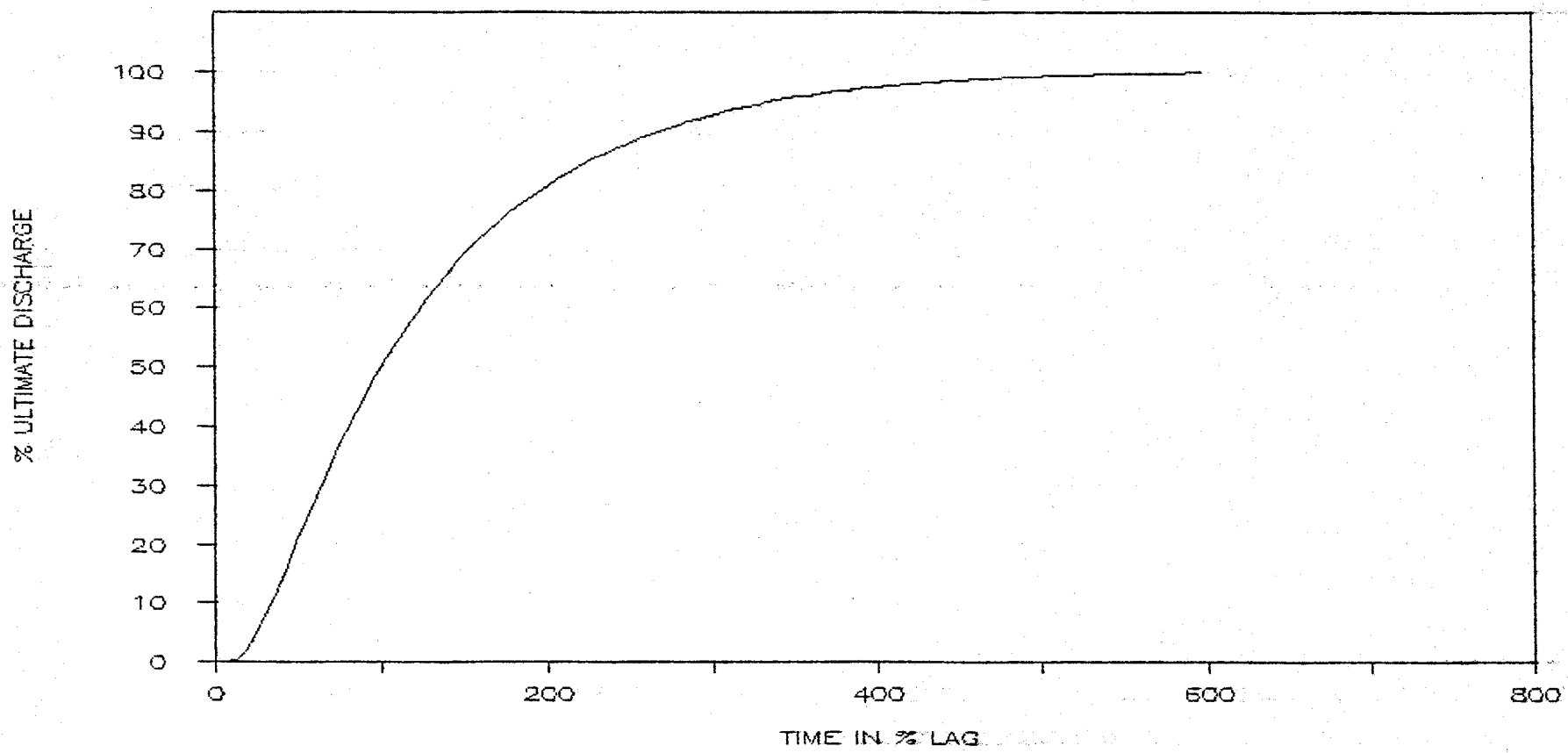
ALA1.04 LA CUEVA ARROYA TRIBUTARY

6 SEPTEMBER 1980



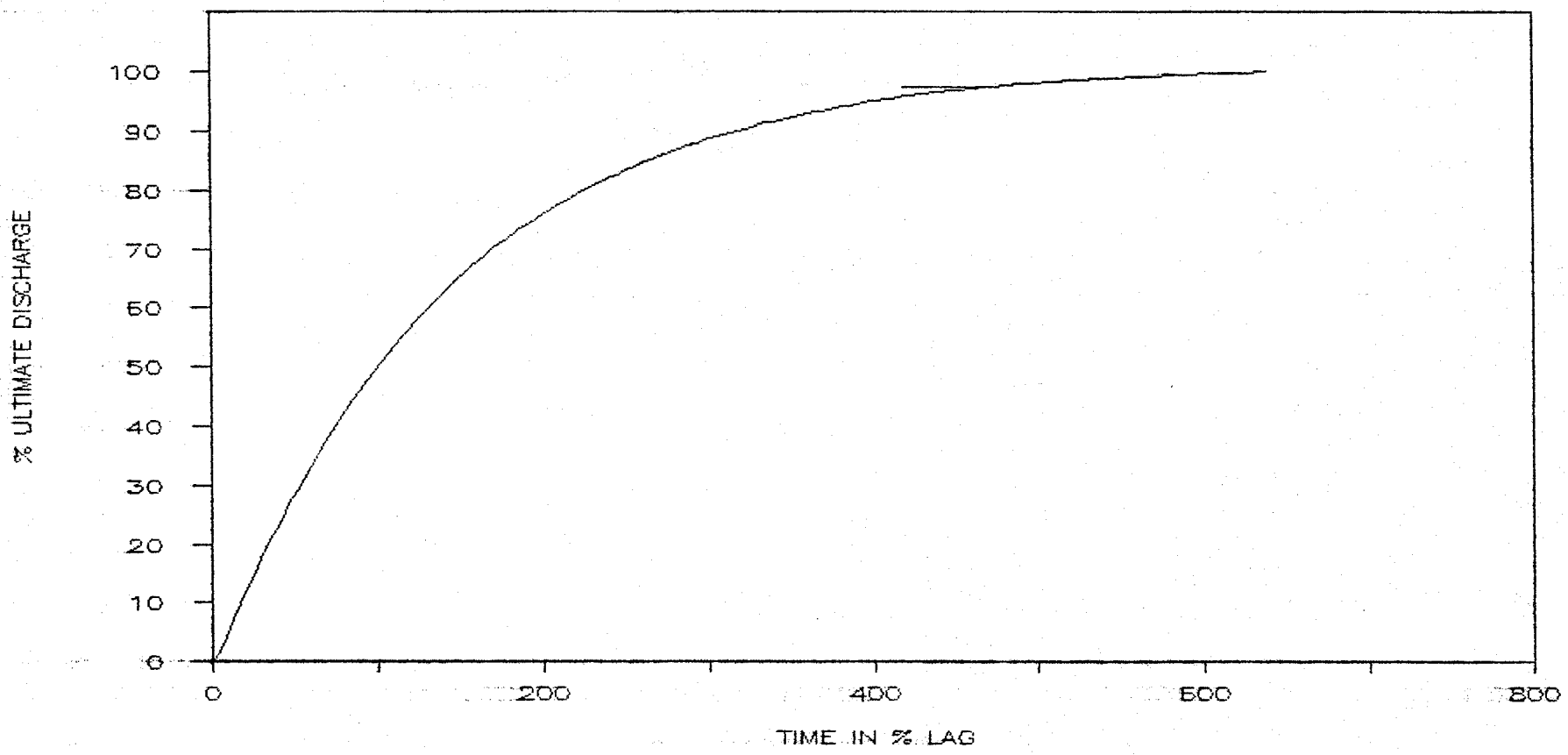
ALA2.02 LA CUEVA ARROYA TRIBUTARY

8 SEPTEMBER 1980



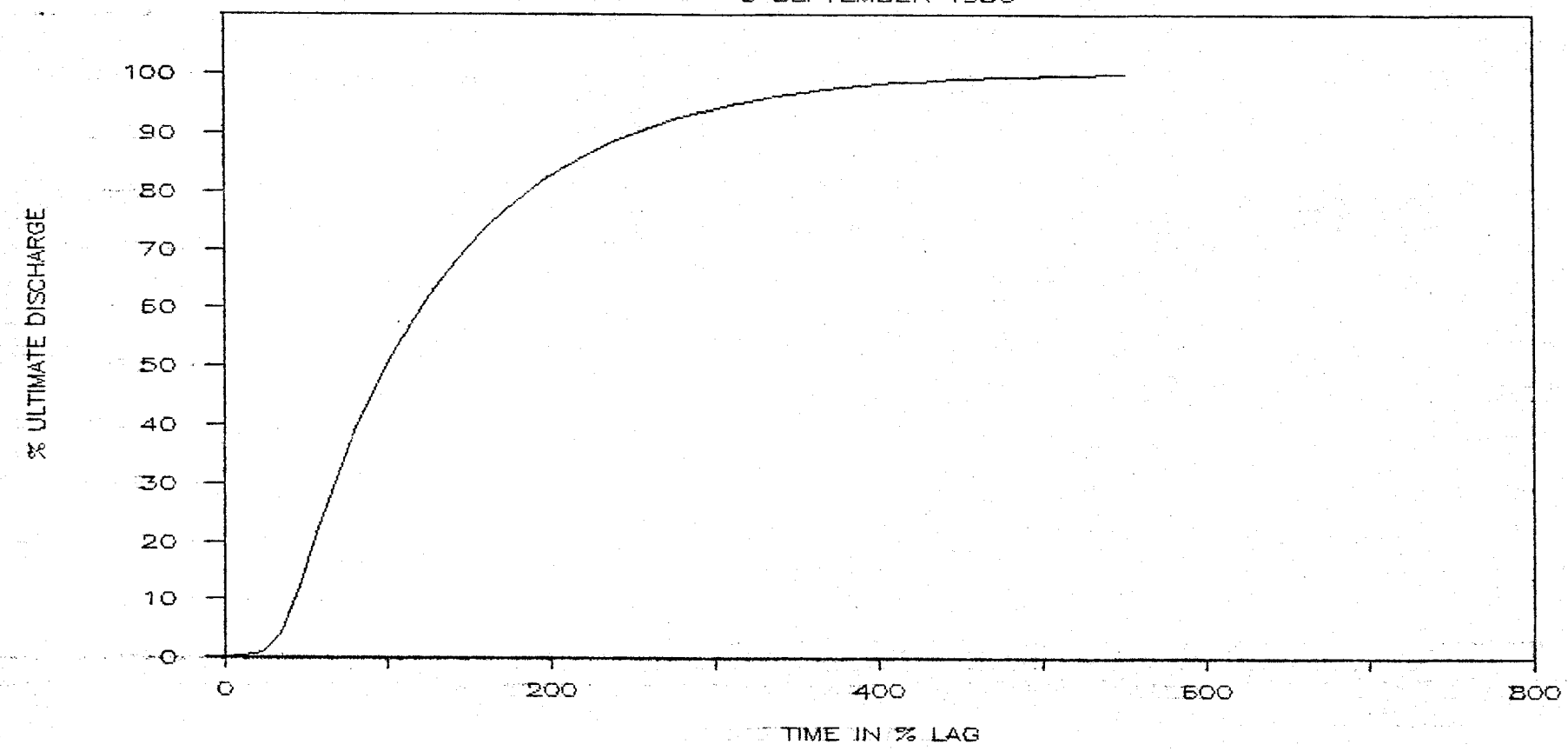
ALA3.02 LA CUEVA ARROYA TRIBUTARY

7 JULY 1981



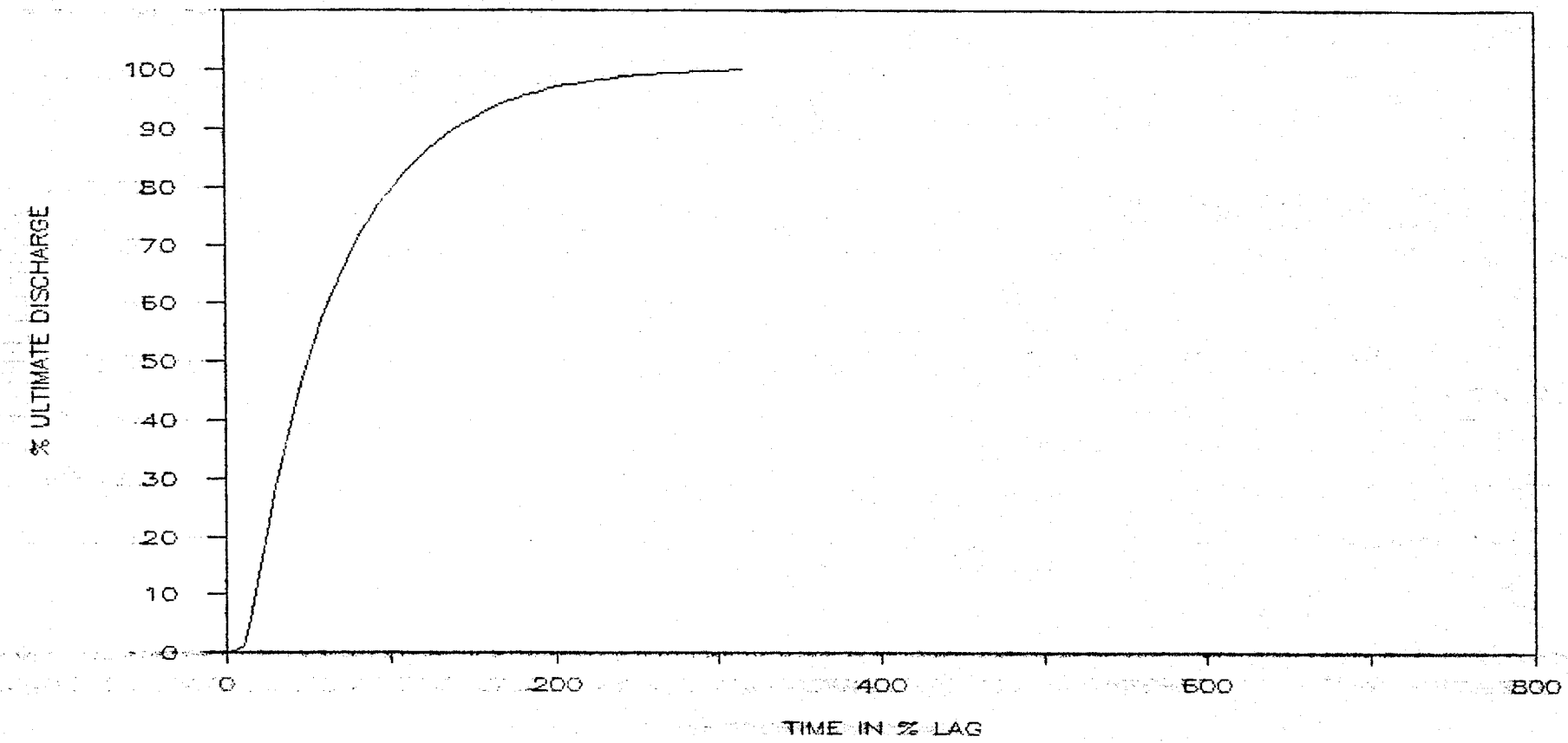
ACA1.04 CAMINO ARROYO TRIBUTARY

6 SEPTEMBER 1980



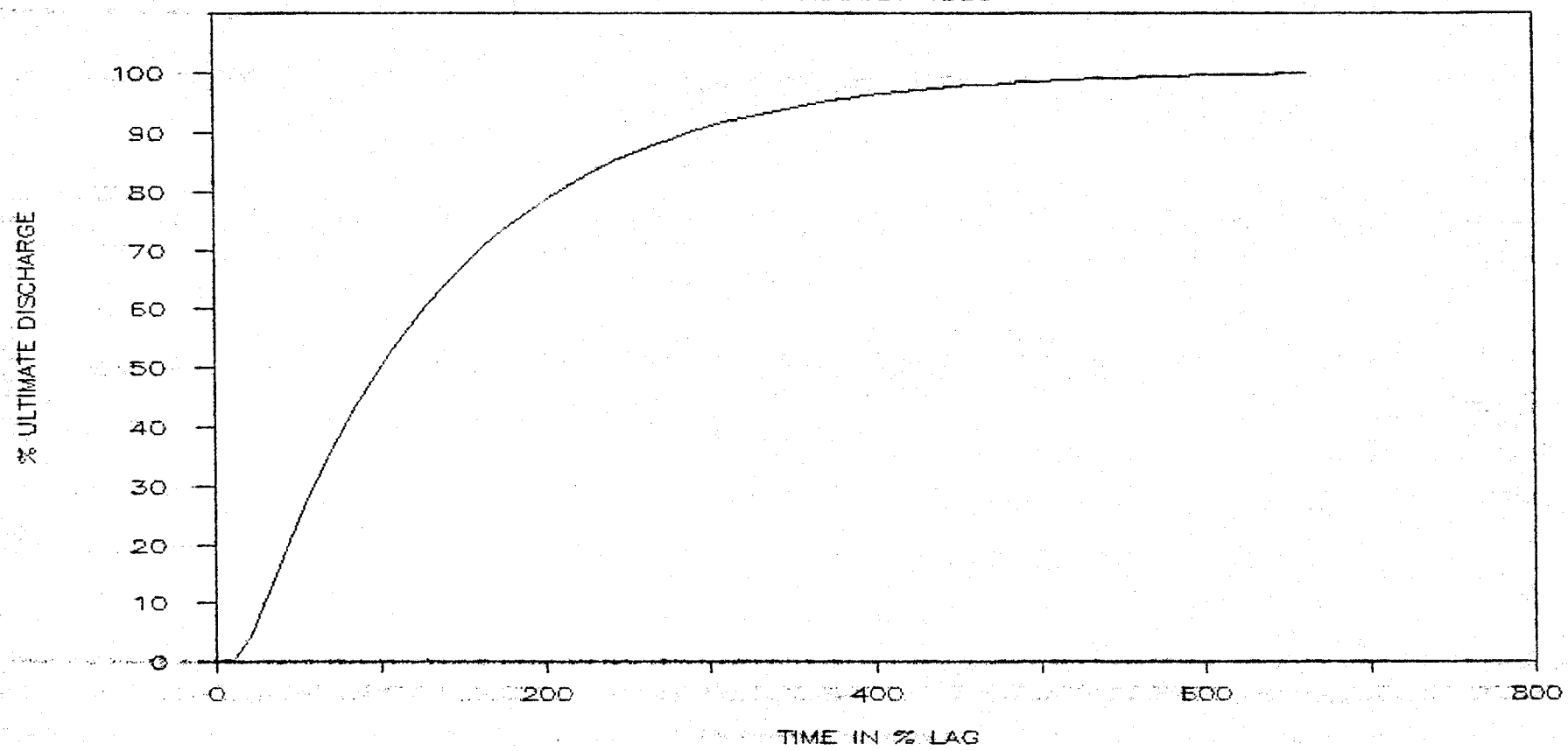
ACA2.03 CAMINO ARROYO TRIBUTARY

7 JULY 1981



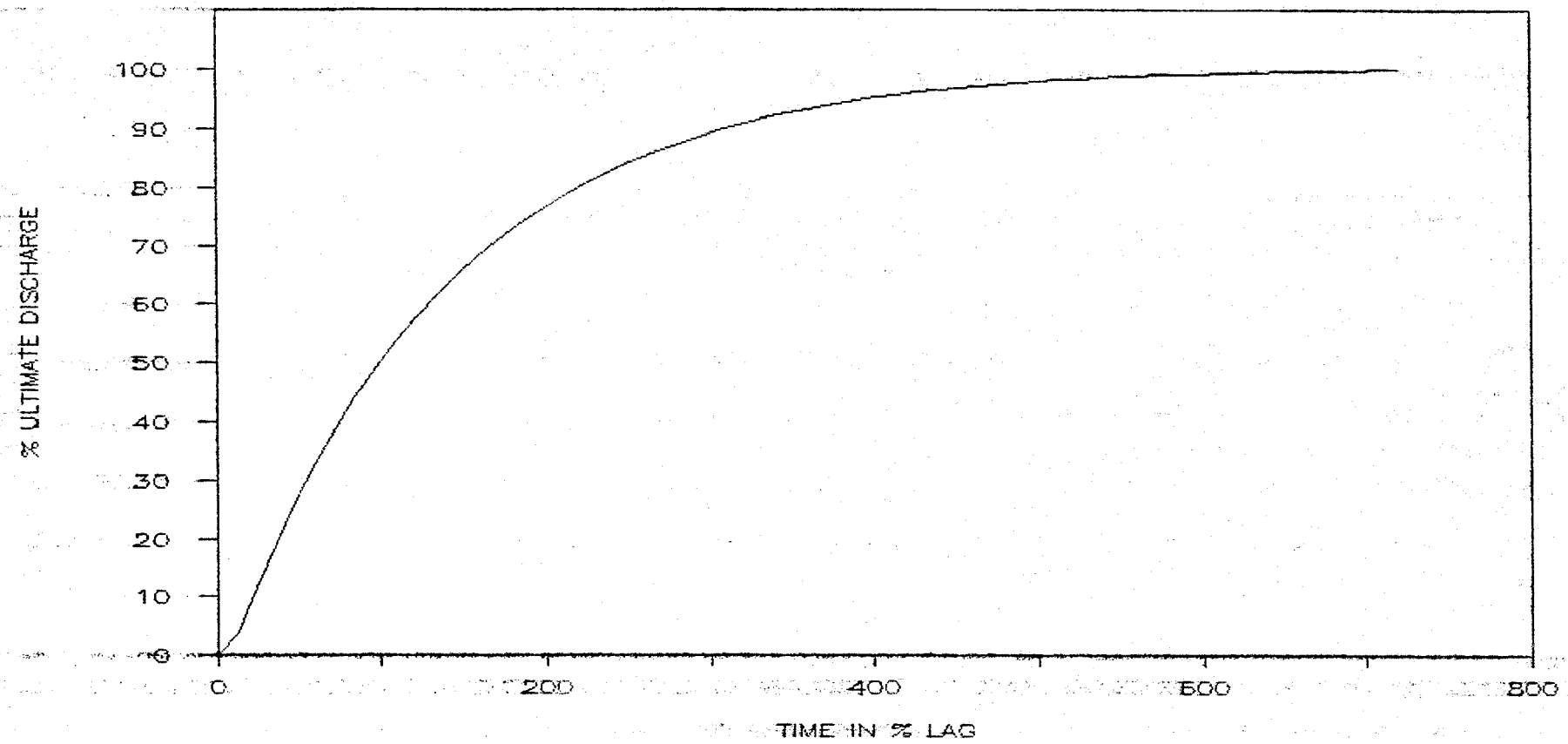
ANCA1.04 NORTH CAMINO ARROYO TRIB.

14 AUGUST 1980



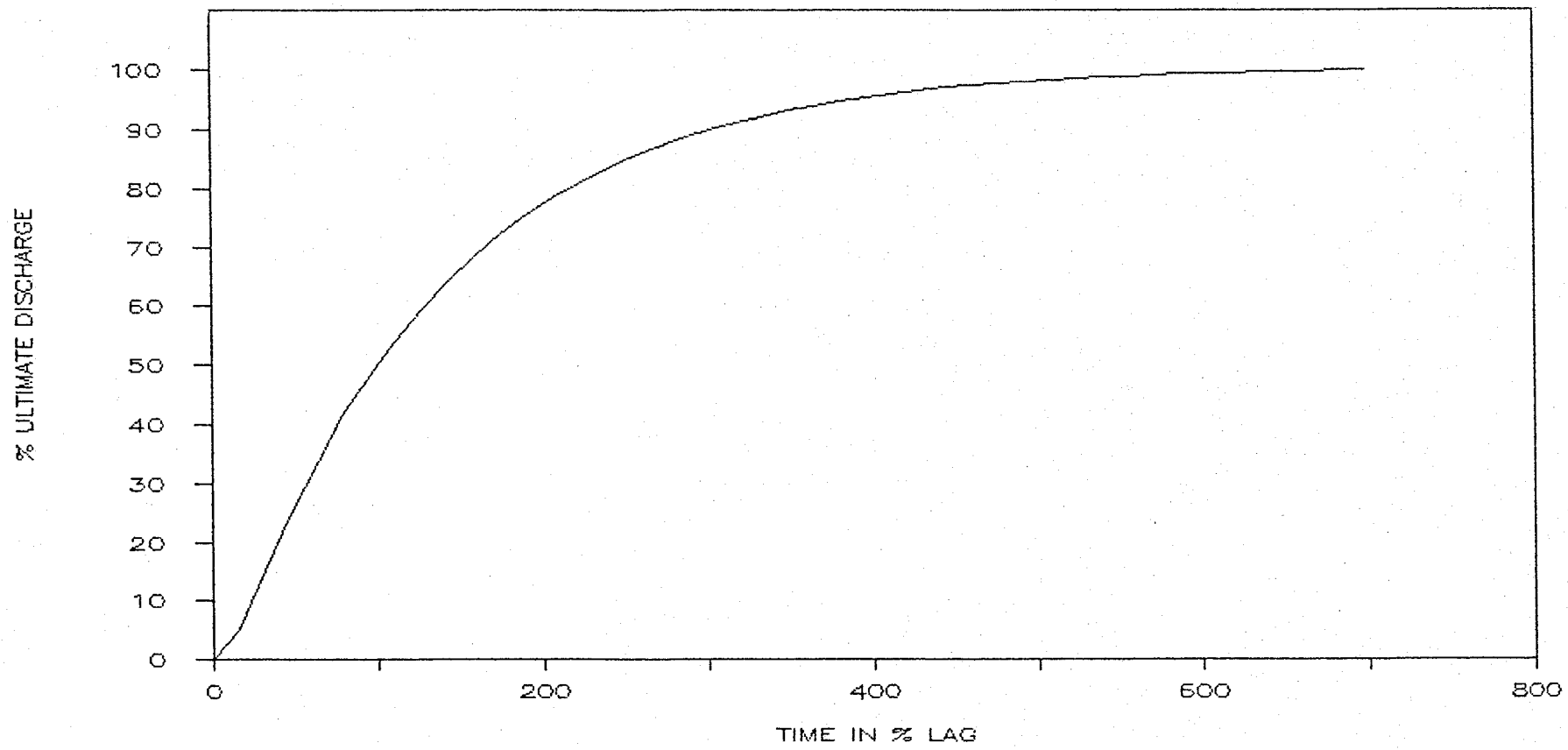
ANCA2.05 NORTH CAMINO ARROYO TRIB.

7 JULY 1981



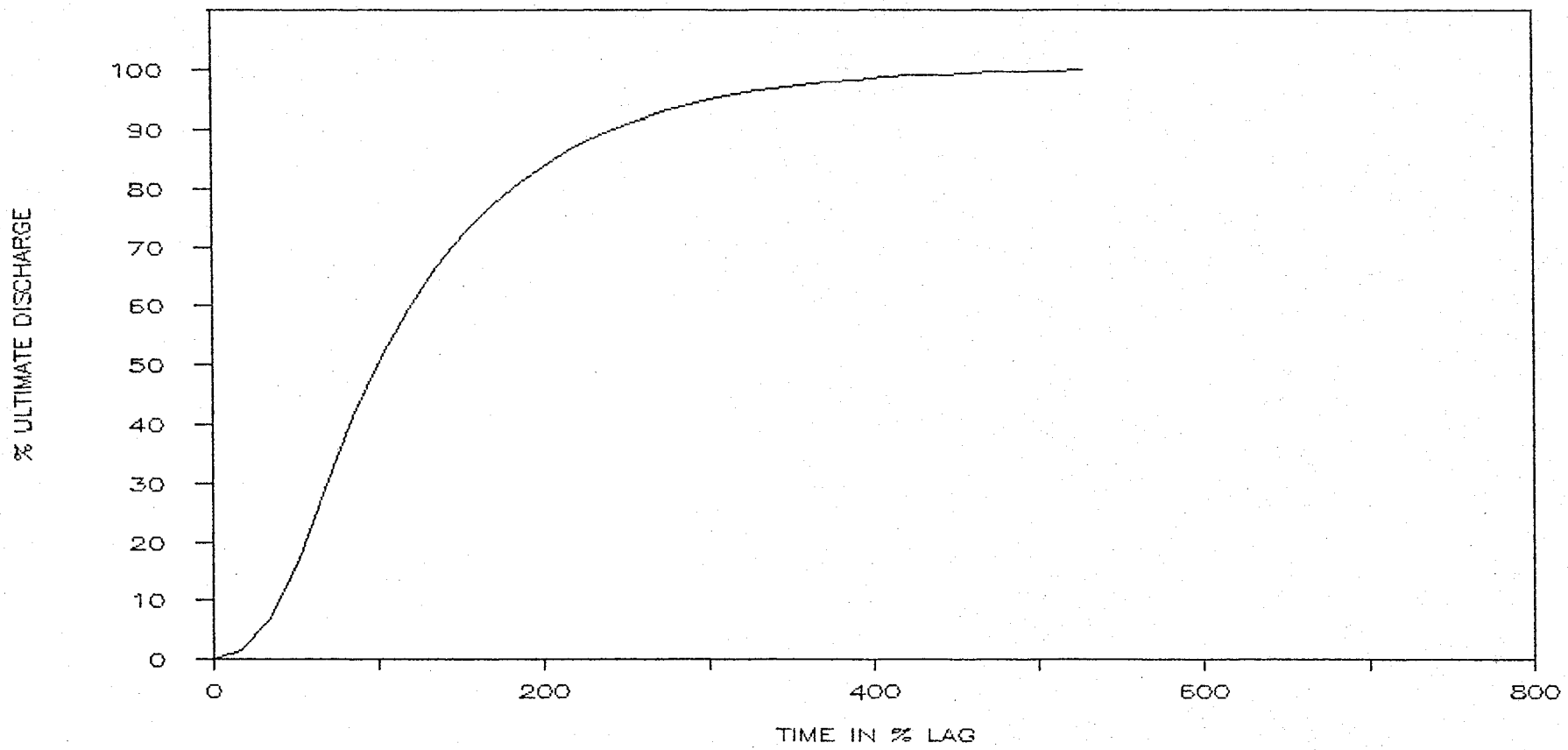
D1161 116 AVE & CLAUDE COURT

3 JUNE 1981



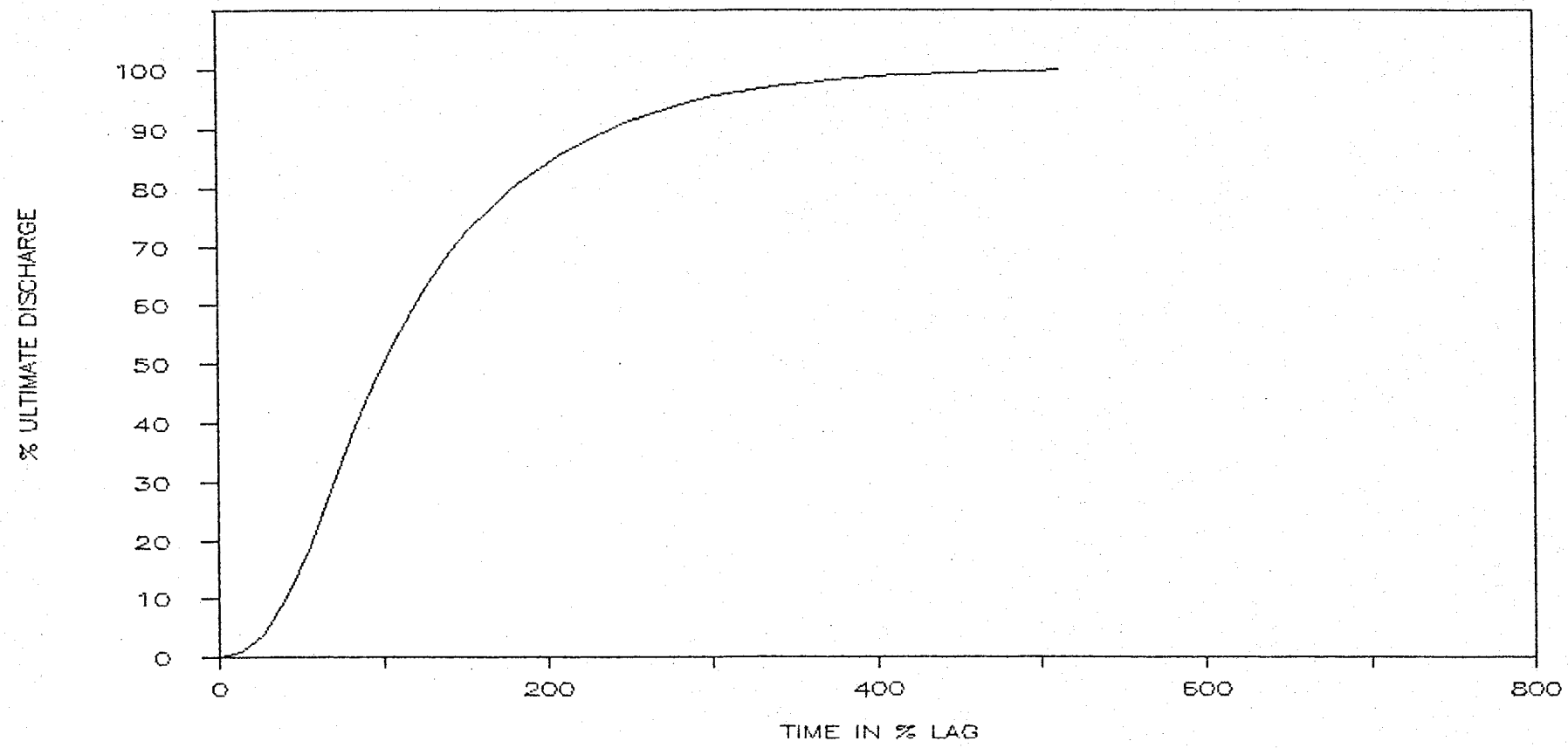
DVI1 VILLA ITALIA STORM DRAIN

20 APRIL 1981



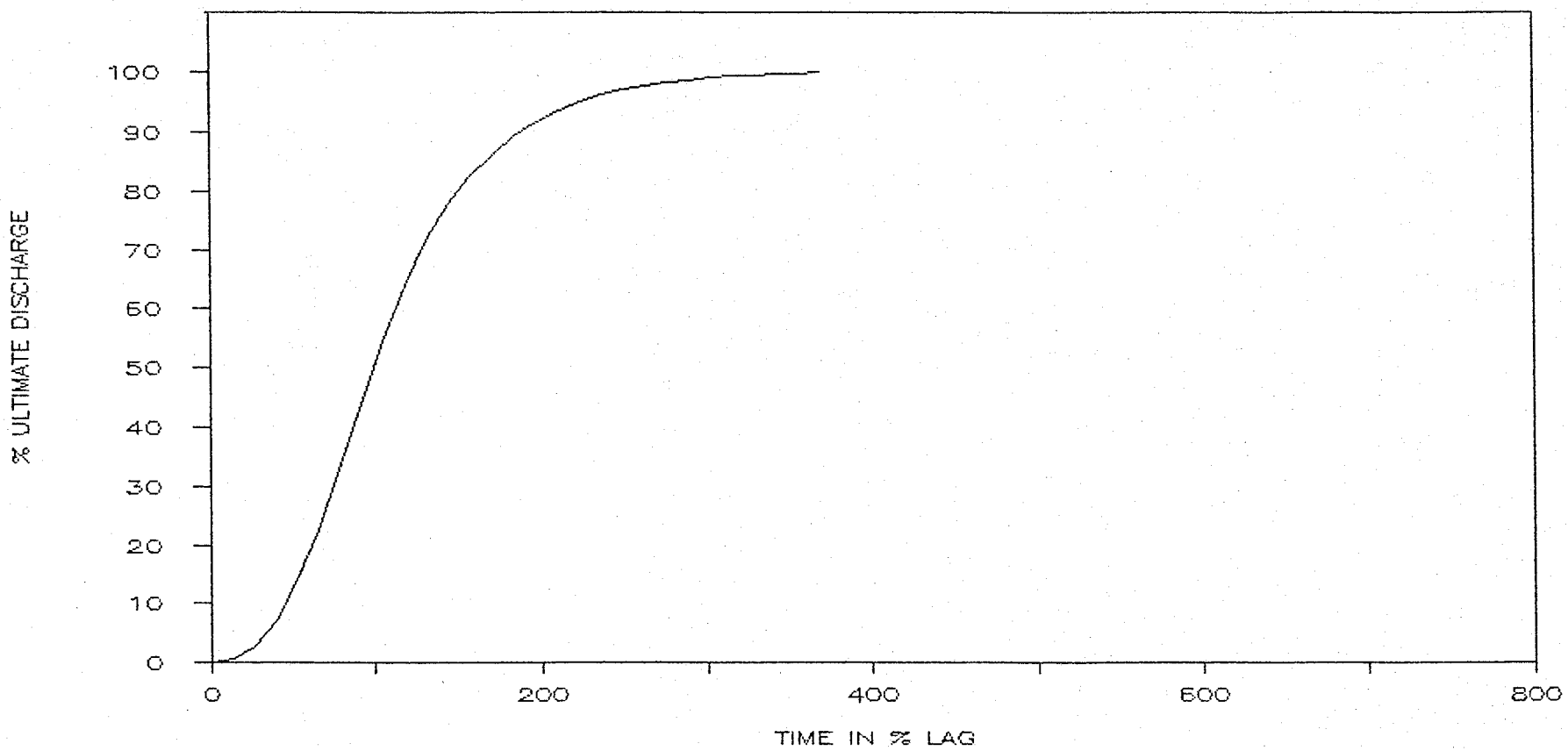
DCD1 CONCOURSE D STAPLETON AIRPORT

1 AUGUST 1976



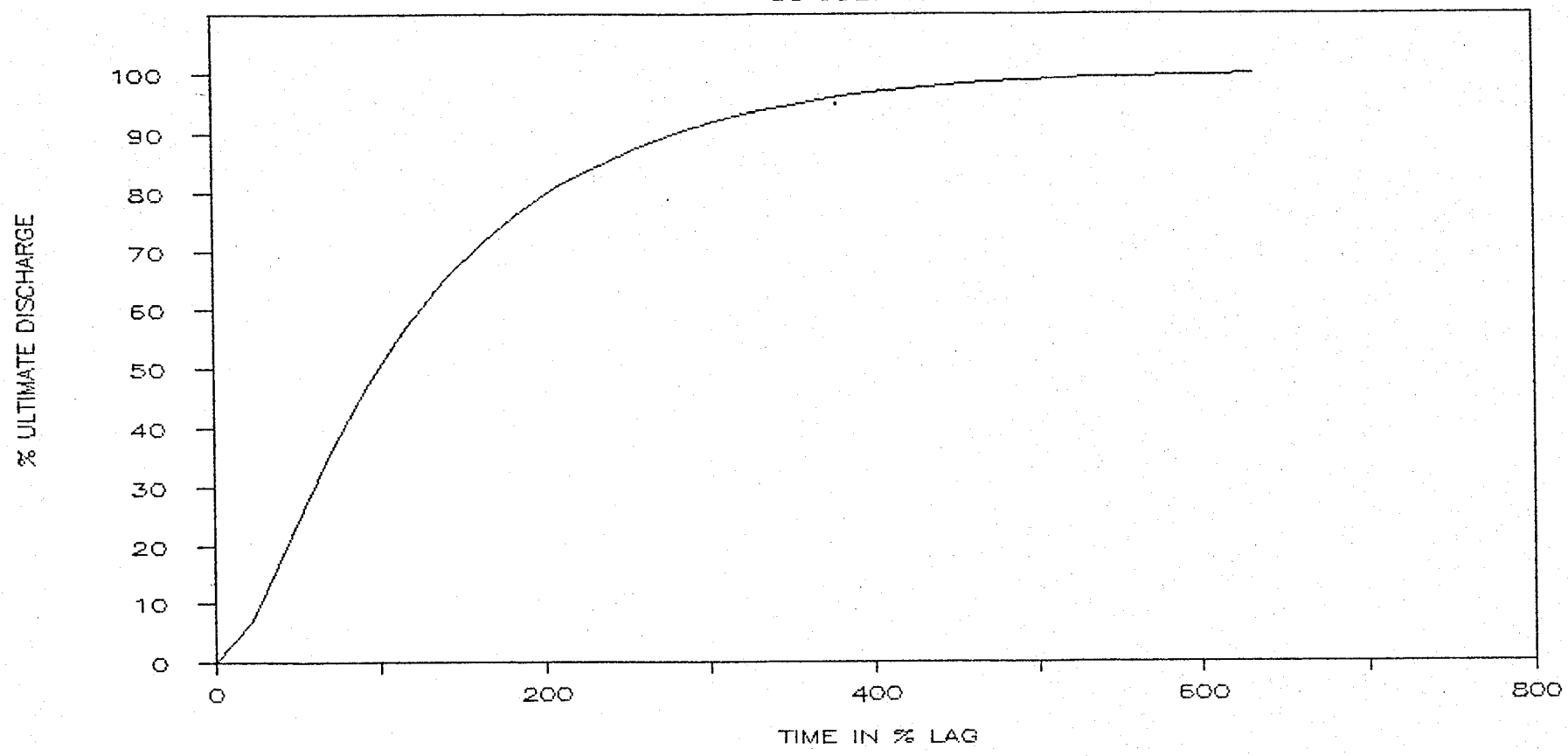
DGC1 GOOSE CREEK AT BOULDER

25 JULY 1976



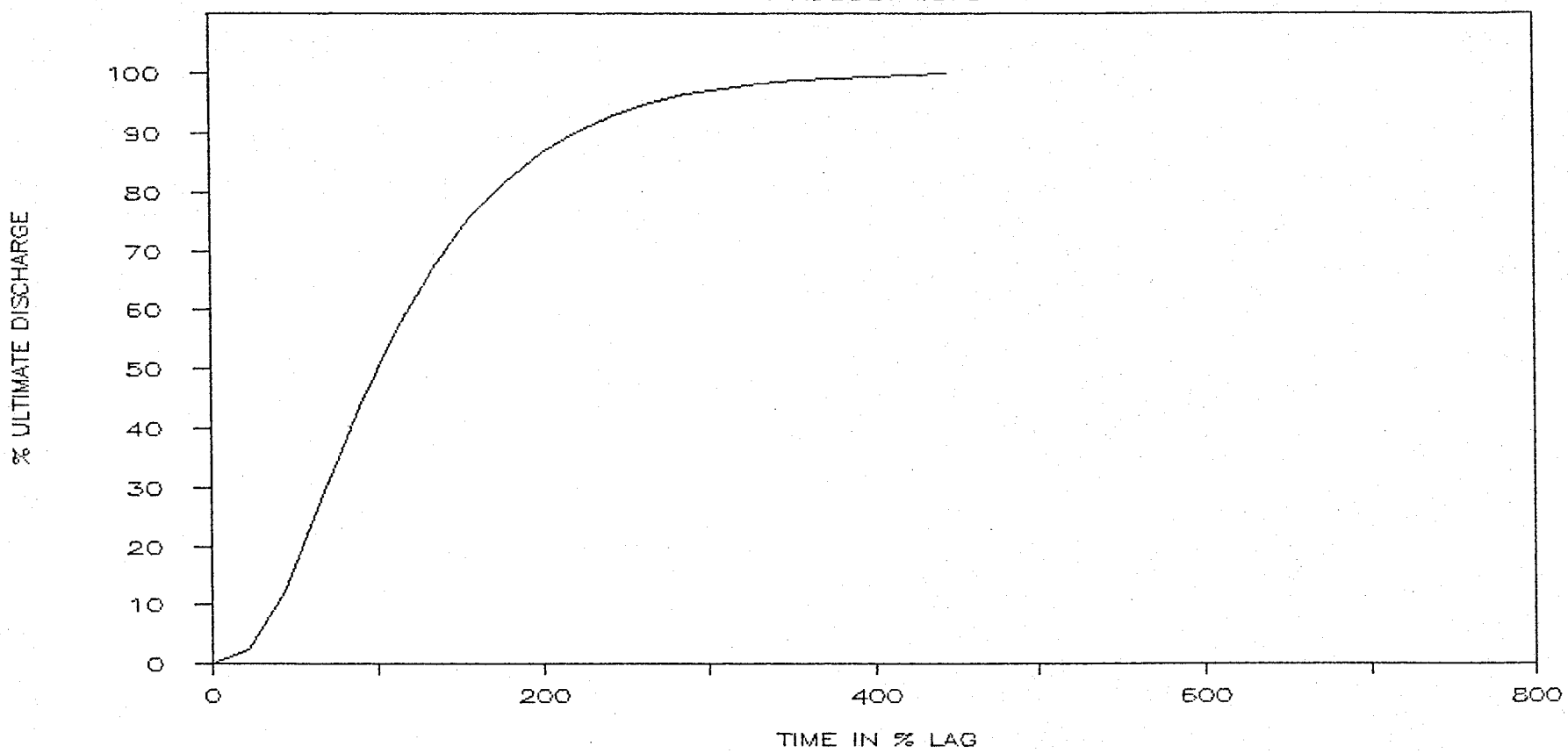
DSC1 SAND CREEK AT DENVER

30 JULY 1974



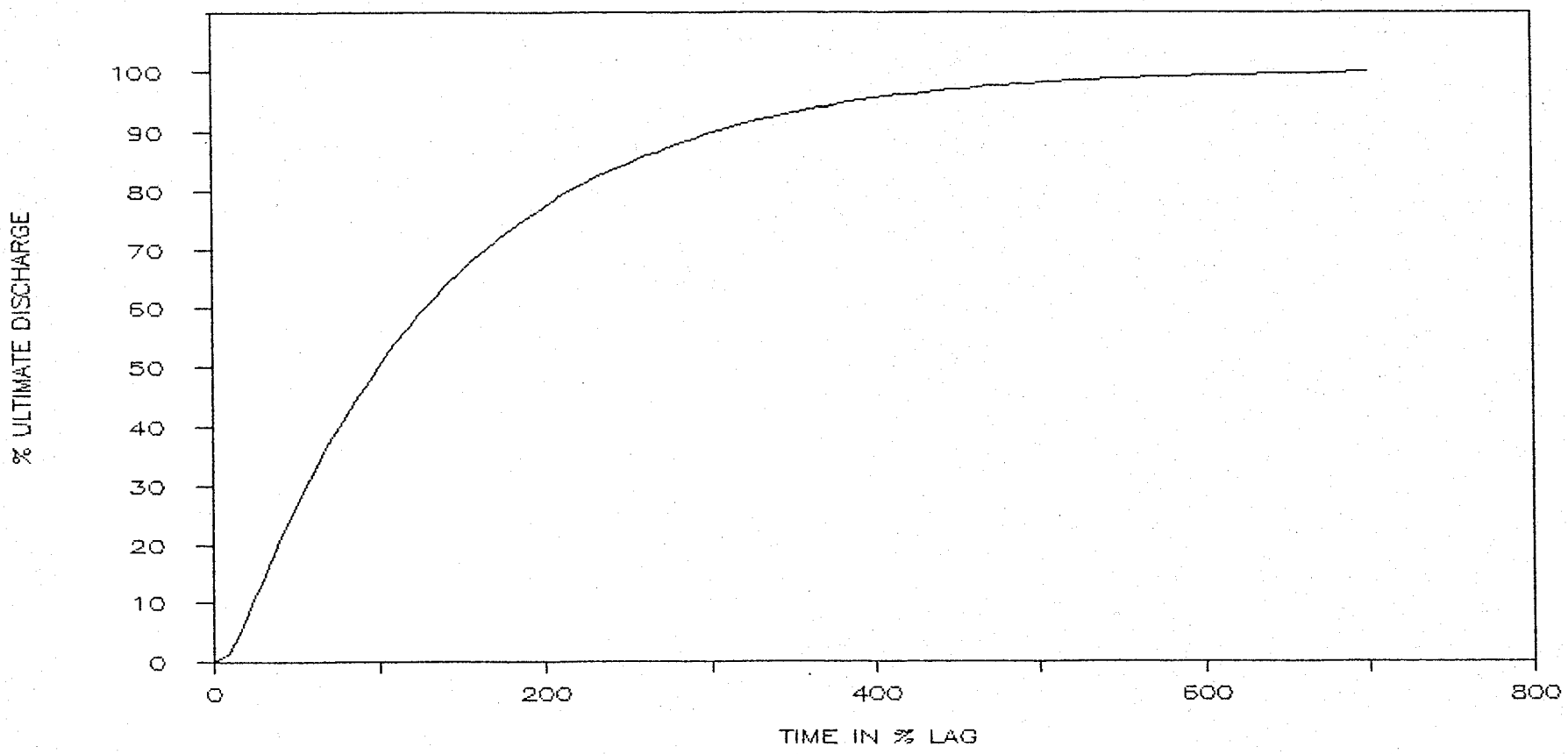
DSC2 SAND CREEK AT DENVER

1 AUGUST 1976



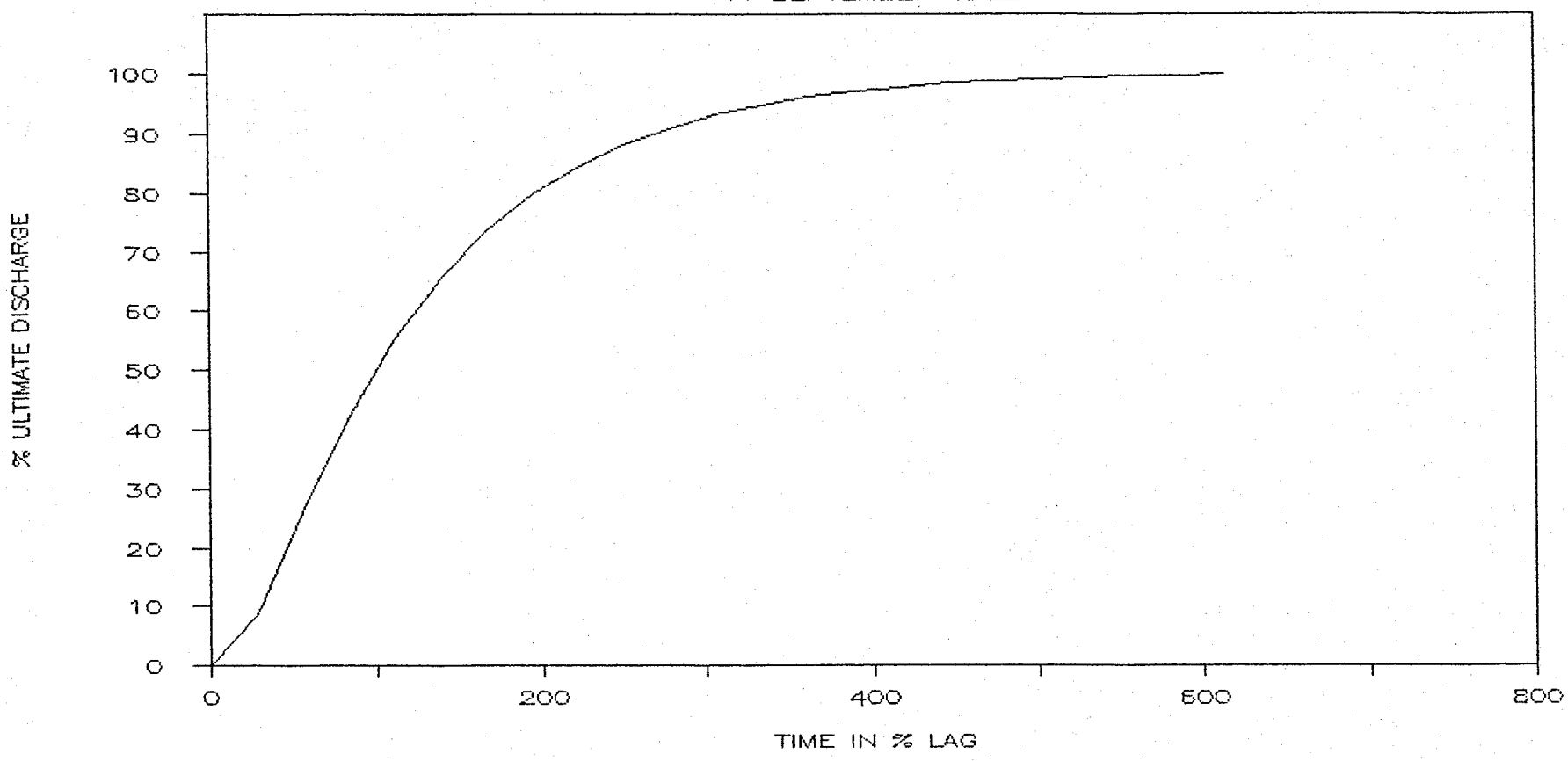
THS1.05 HIGH SCHOOL WASH

13 AUGUST 1980



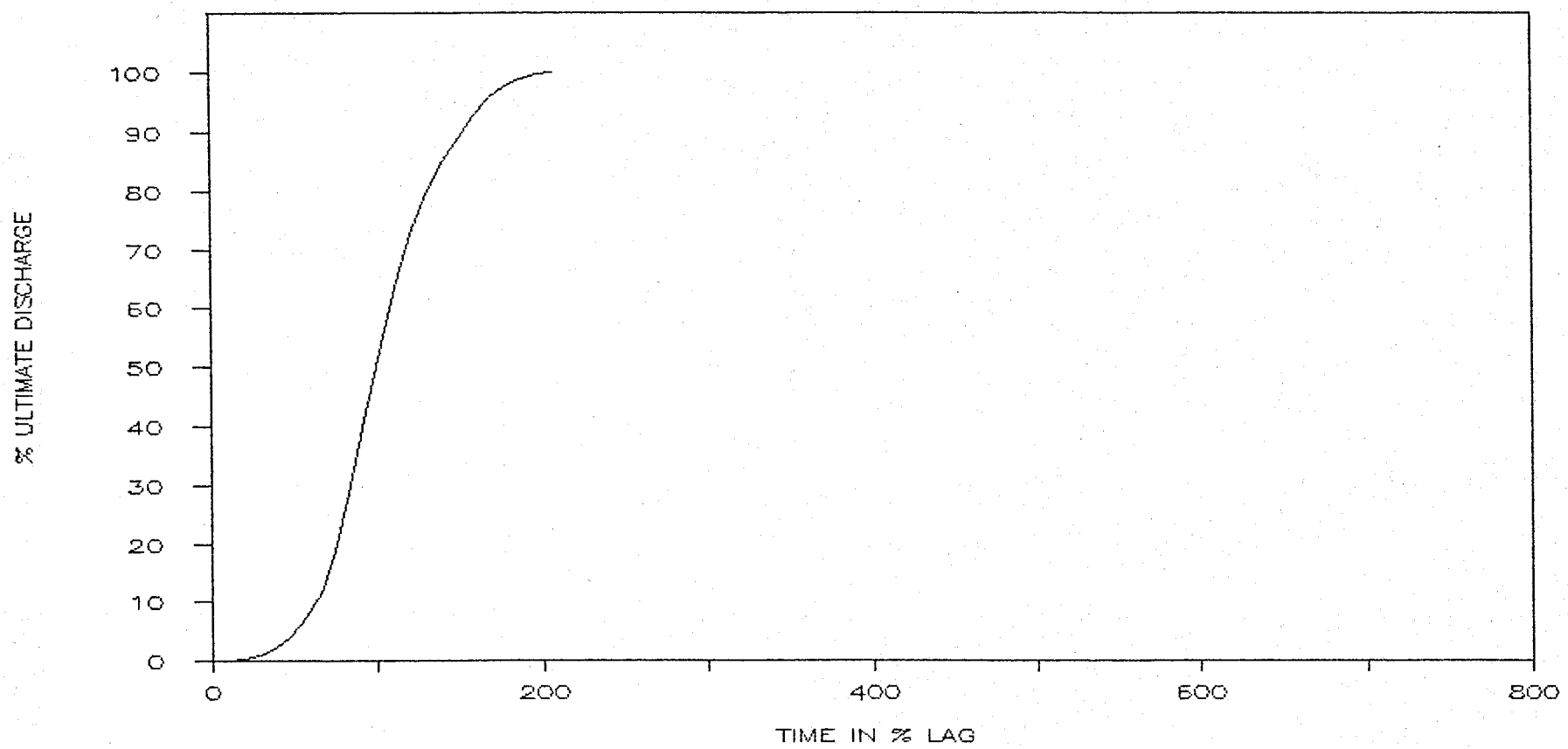
THS2.02 HIGH SCHOOL WASH

11 SEPTEMBER 1982



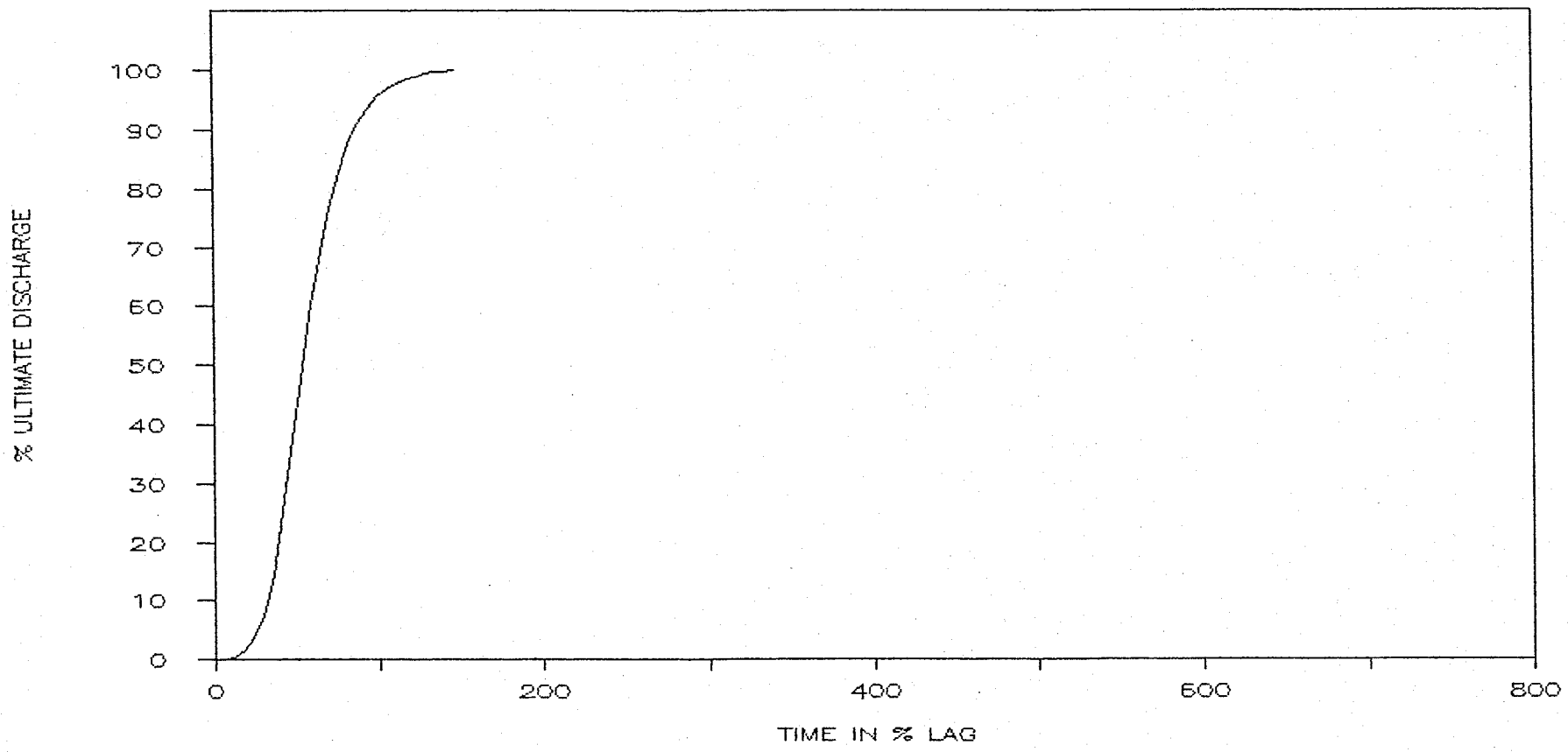
TAR1.07 ARCADIA WASH

1 SEPTEMBER 1971



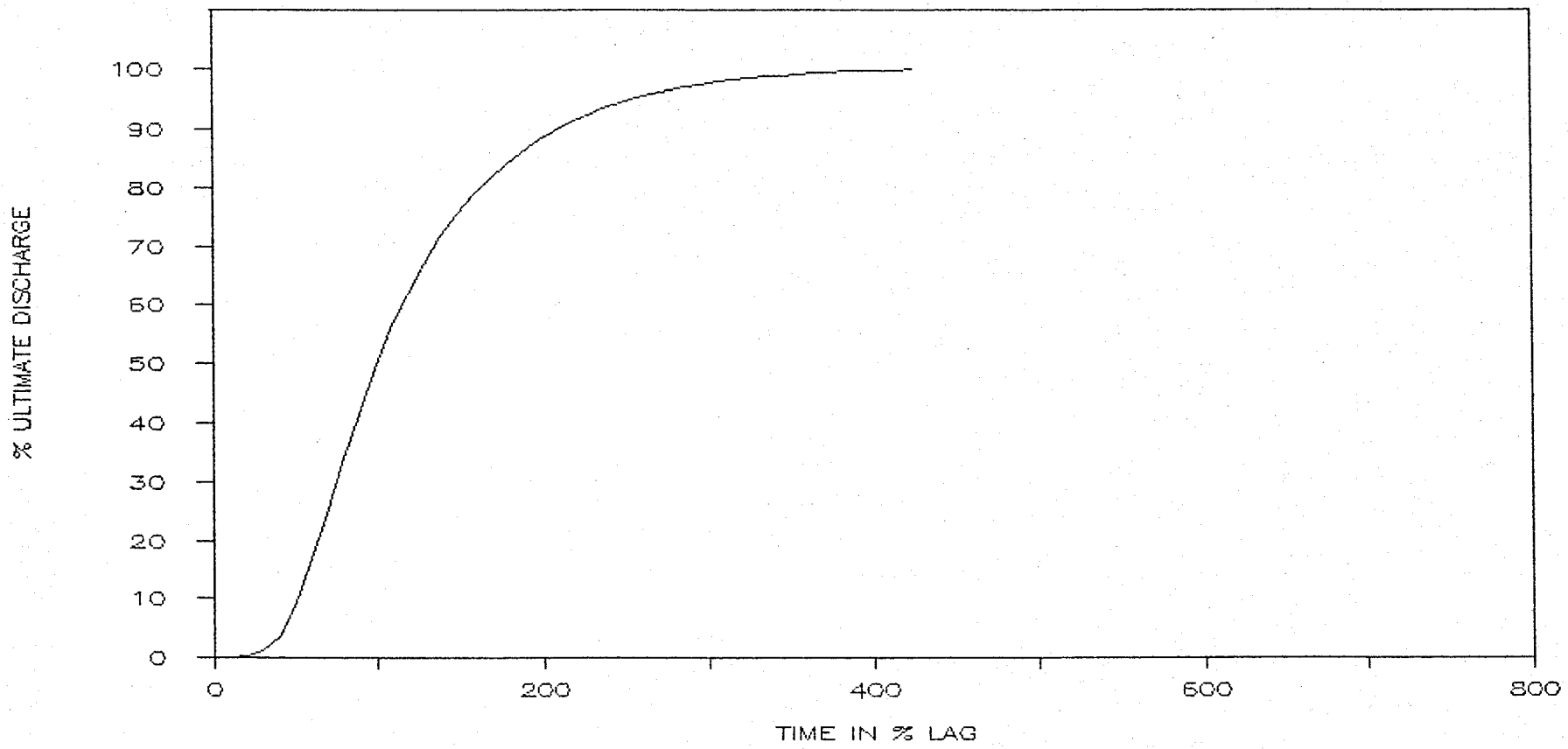
TAR2.03 ARCADIA WASH

23 AUGUST 1982



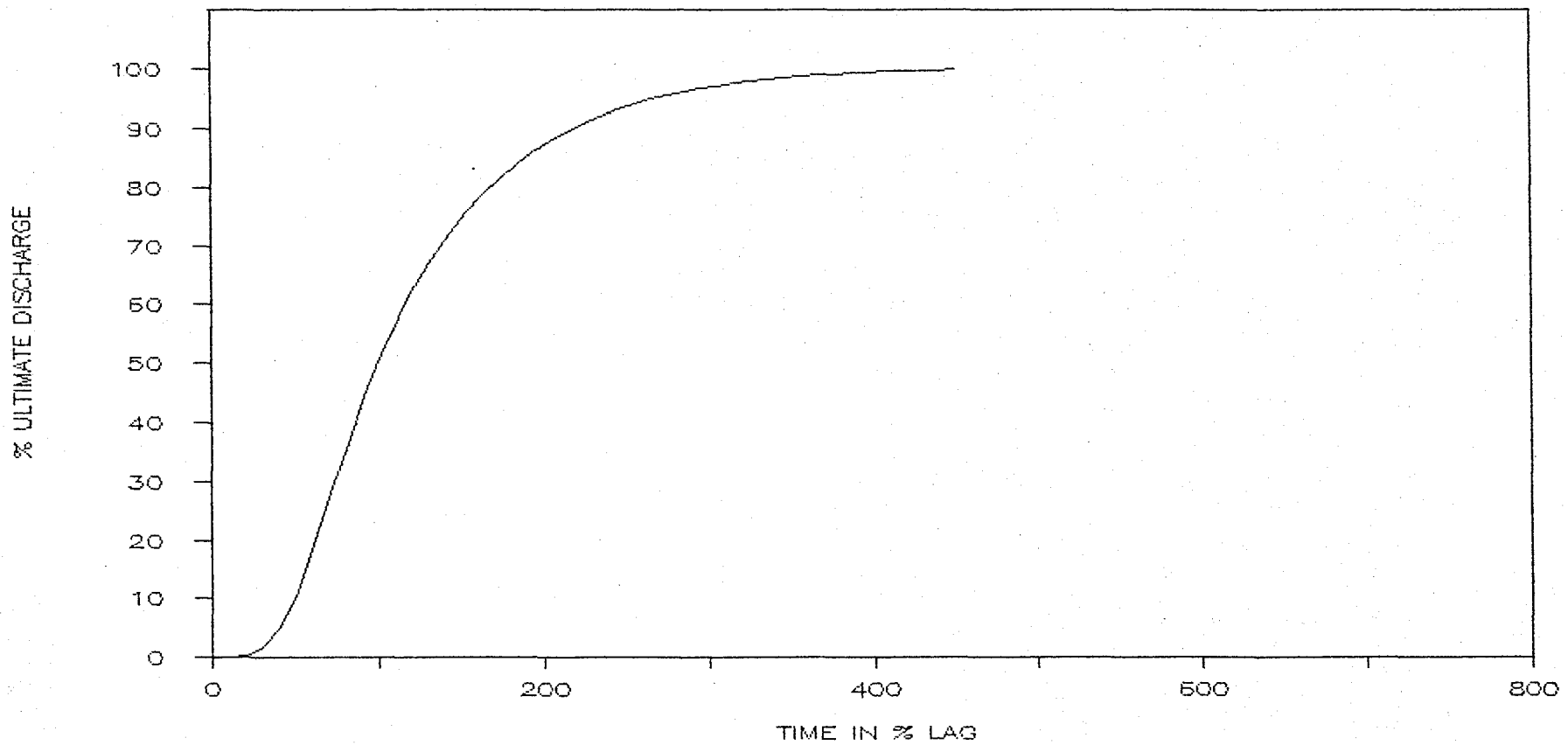
TAR3.04 ARCADIA WASH

11 SEPTEMBER 1982 PART 1



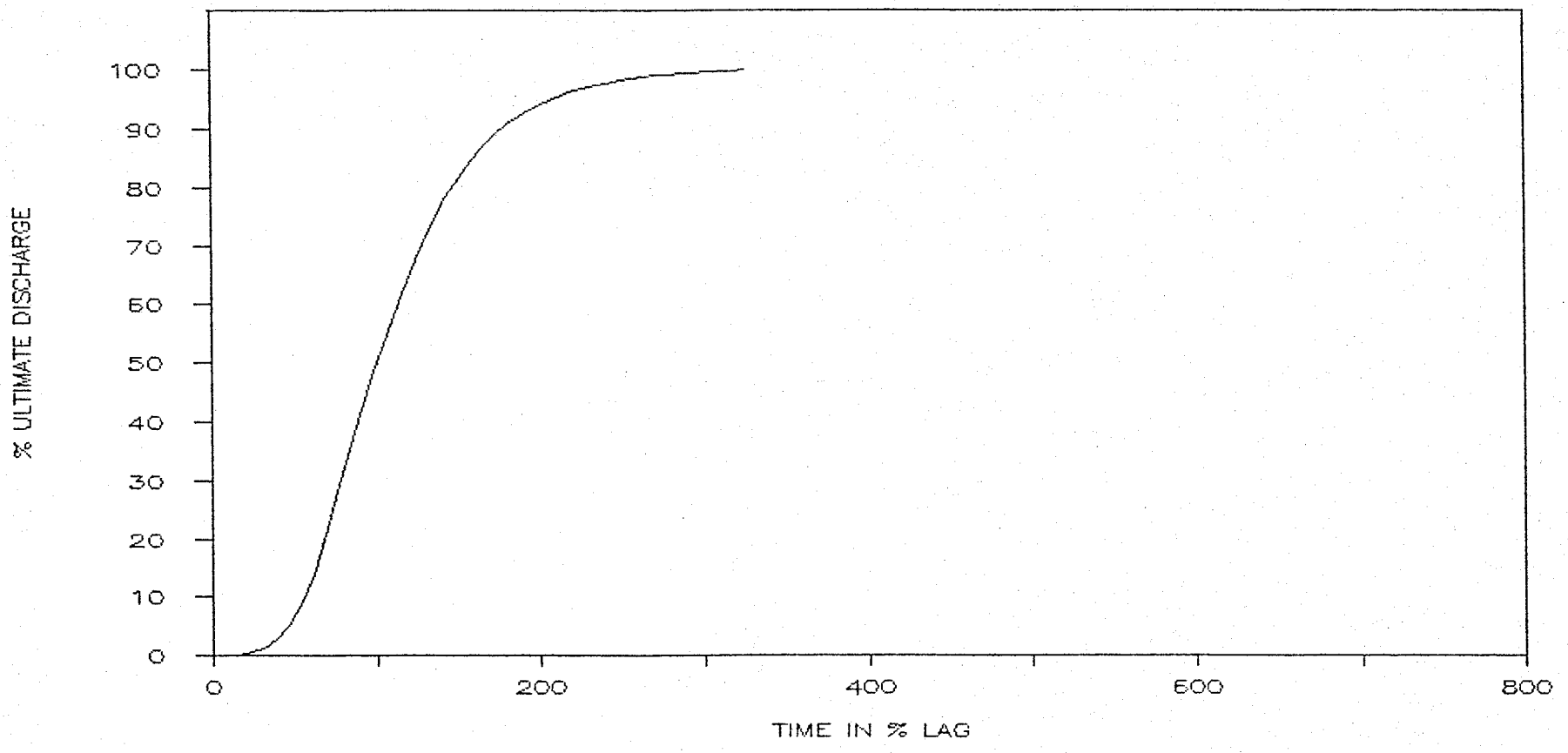
TAR4.03 ARCADIA WASH

11 SEPTEMBER 1982 PART 2



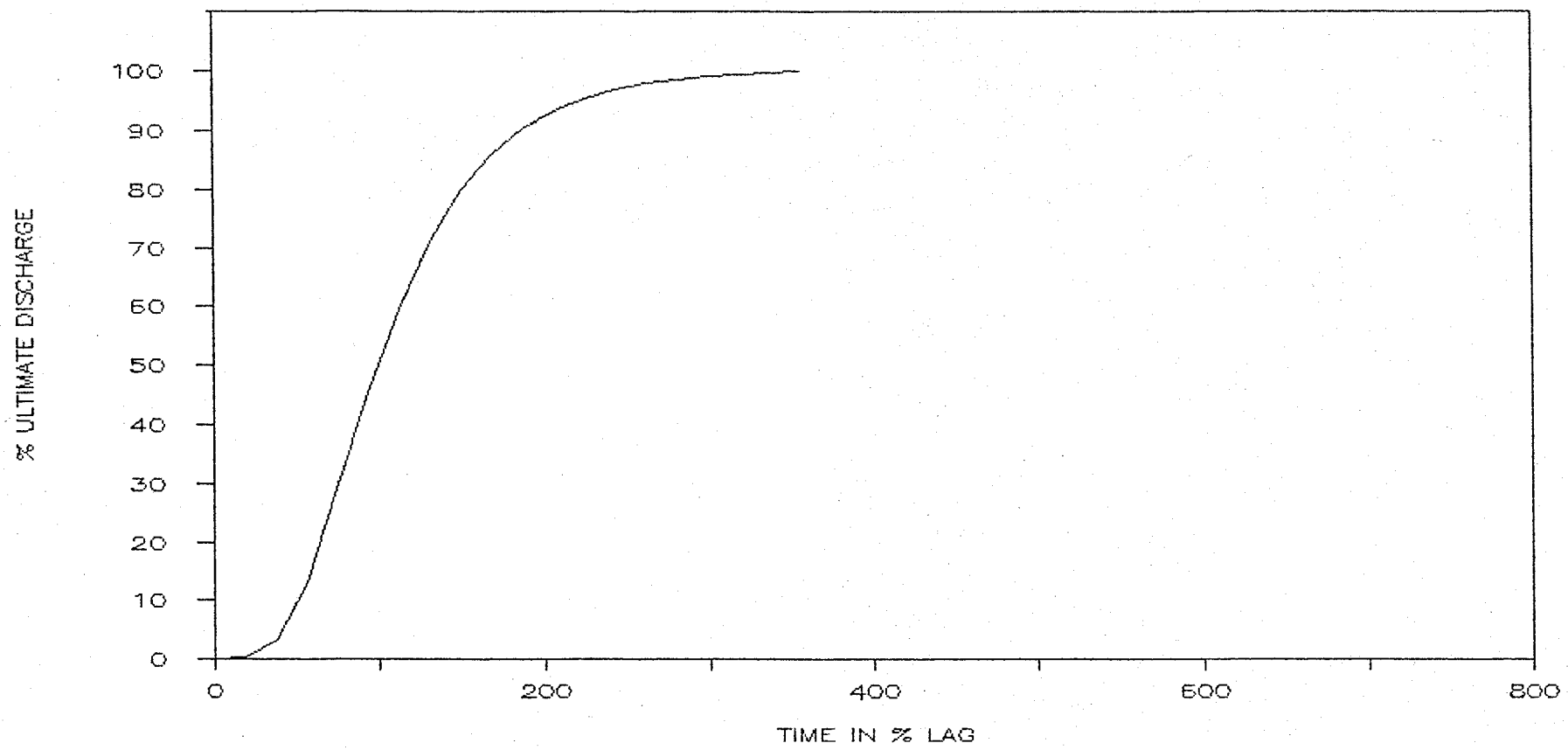
TRR1.07 RAILROAD WASH

11—12 SEPTEMBER 1982



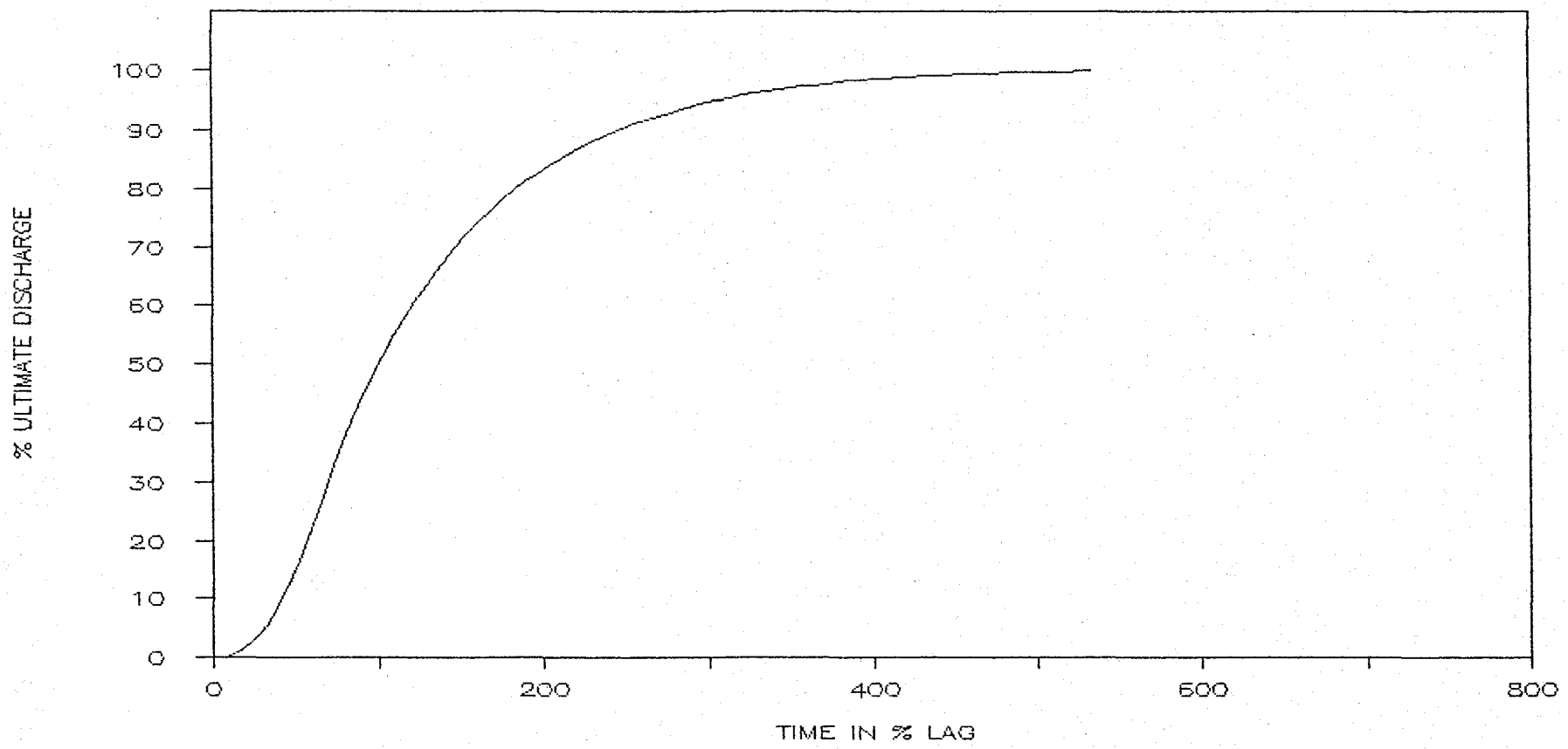
TRR2.04 RAILROAD WASH

2 AUGUST 1982



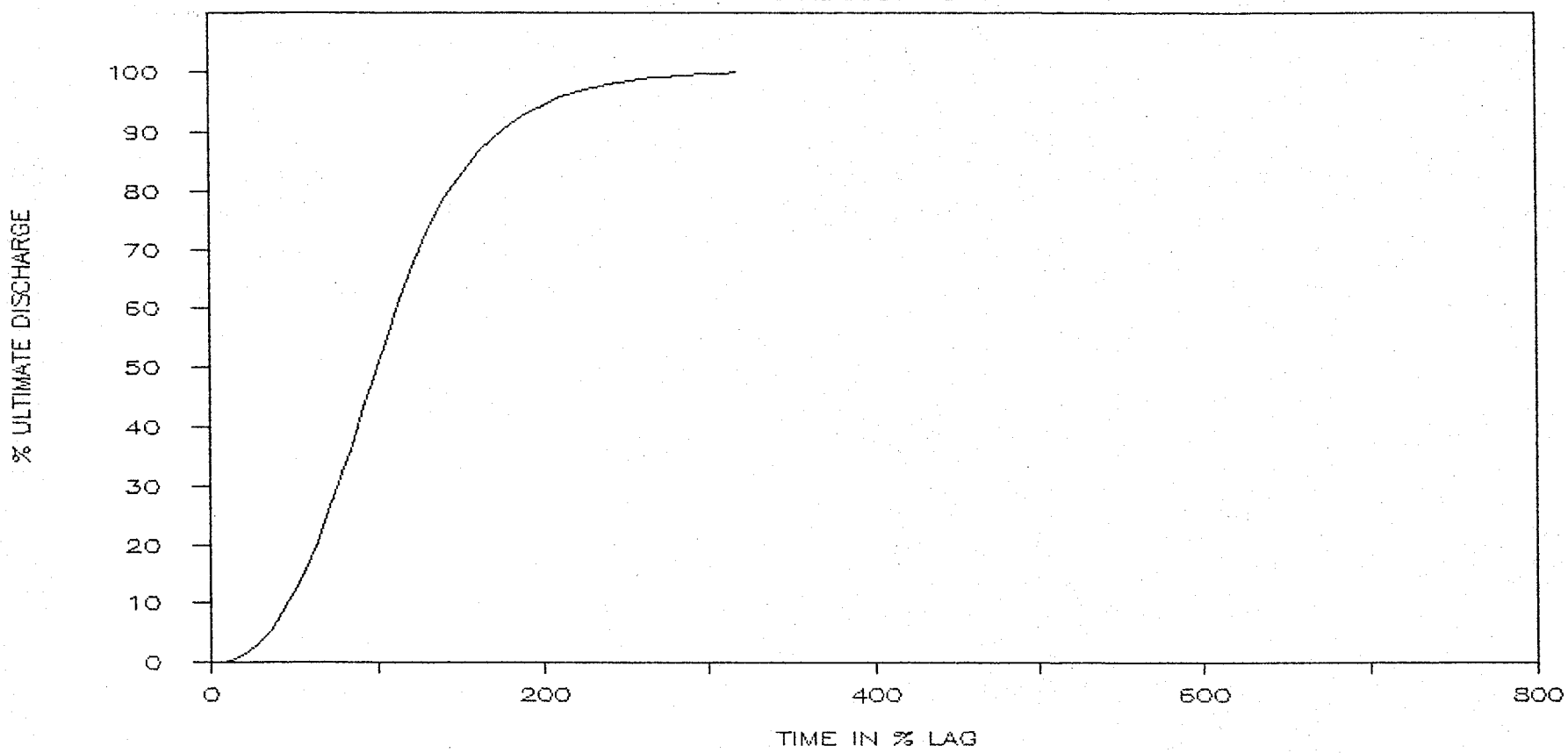
TAT1.03 ATTERBURY WATERSHED

26 SEPTEMBER 1984



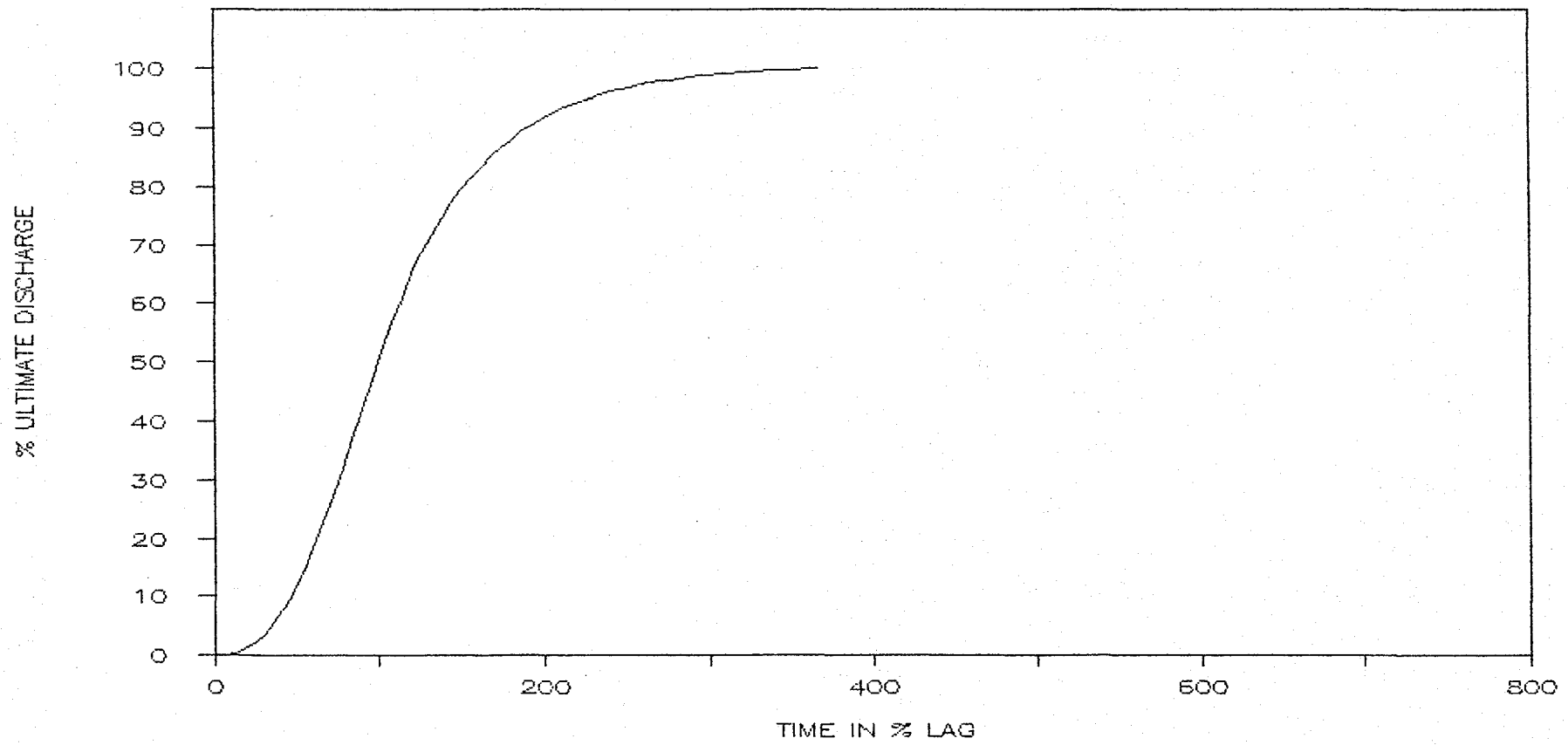
4-1.01 WALNUT GULCH WATERSHED 63.004

10 AUGUST 1971



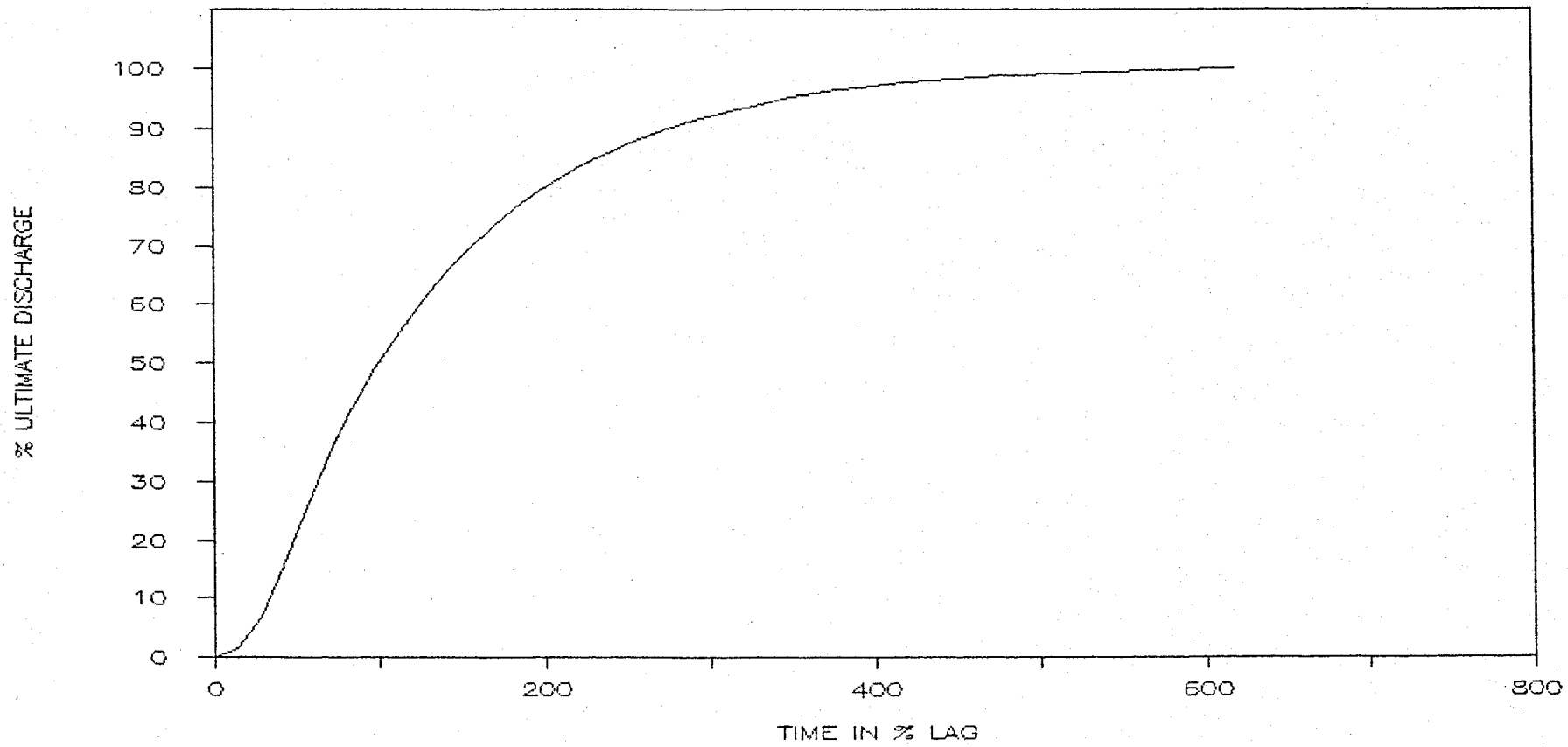
4-2.02 WALNUT GULCH WATERSHED 63.004

17 AUGUST 1961



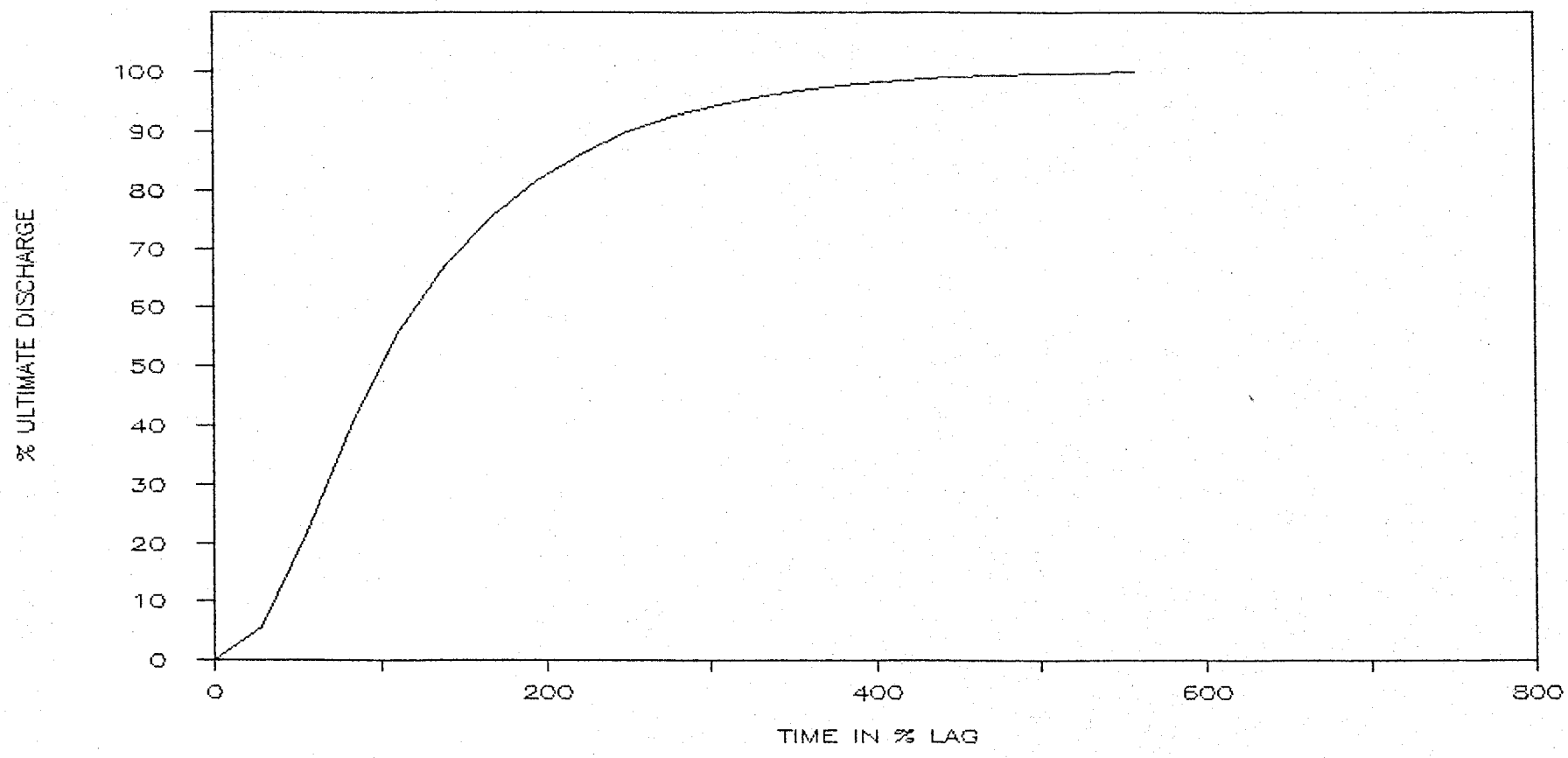
8-1.06 WALNUT GULCH WATERSHED 63.008

6 SEPTEMBER 1976



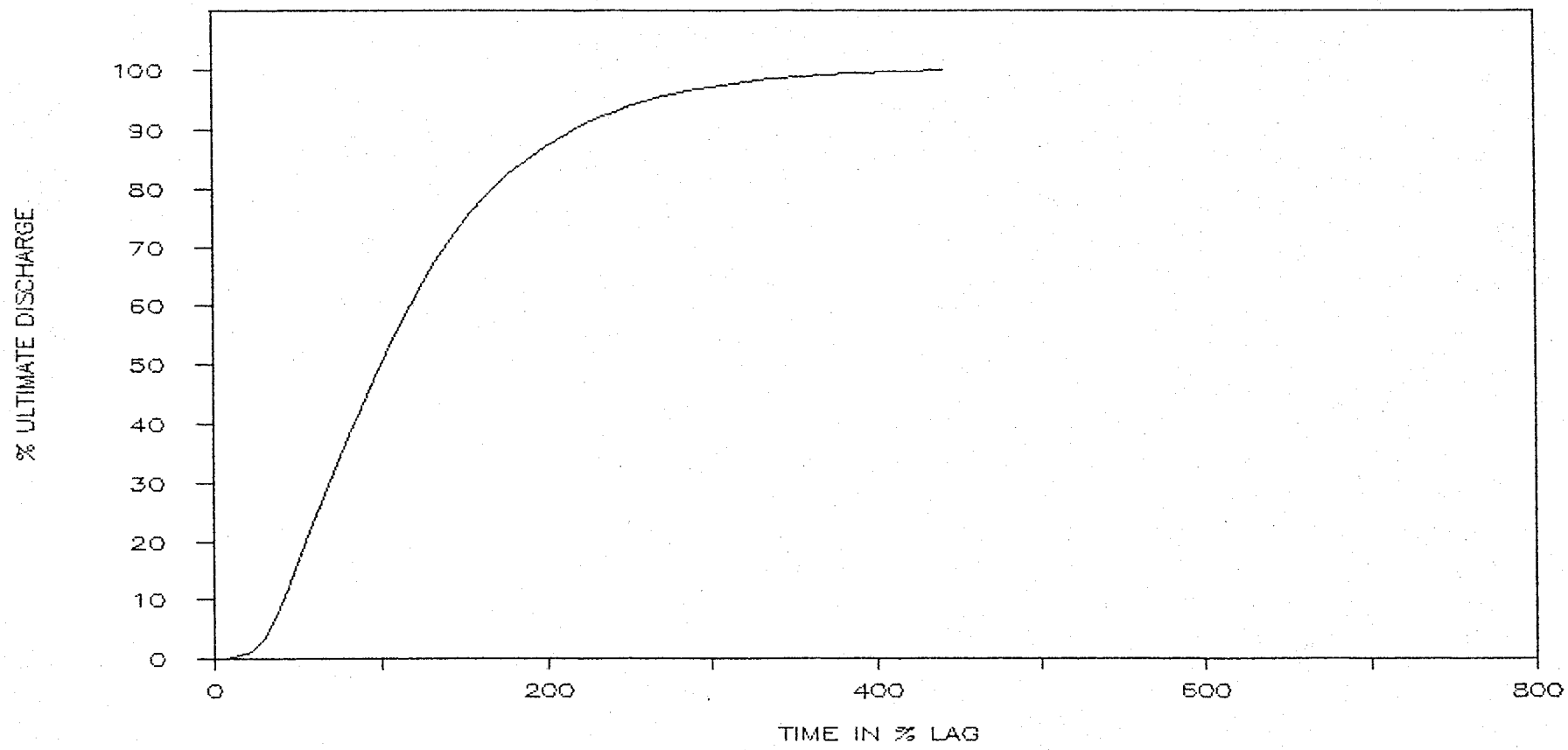
8-2.01 WALNUT GULCH WATERSHED 63.008

10 AUGUST 1971



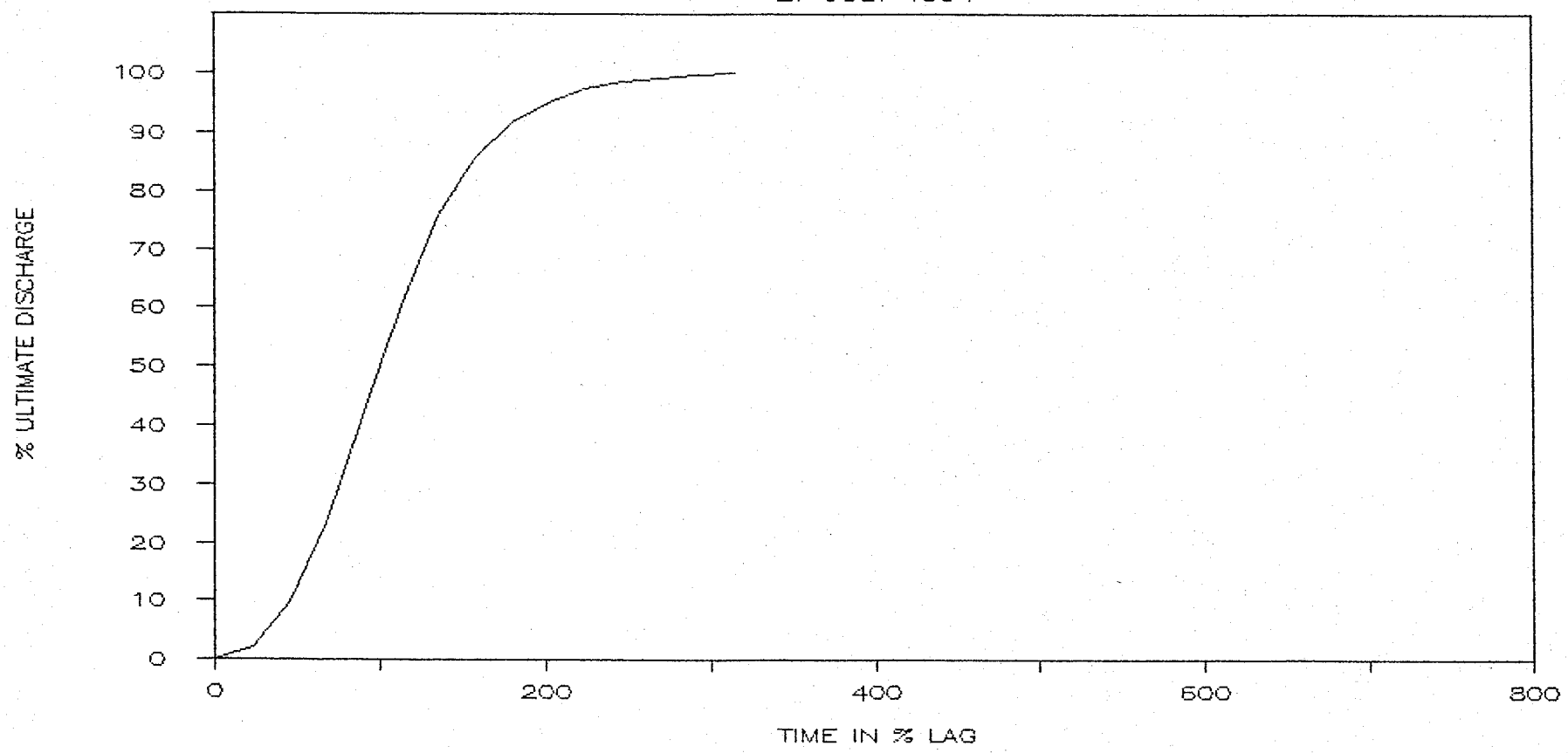
11-1.04 WALNUT GULCH WATERSHED 63.011

13 SEPTEMBER 1975



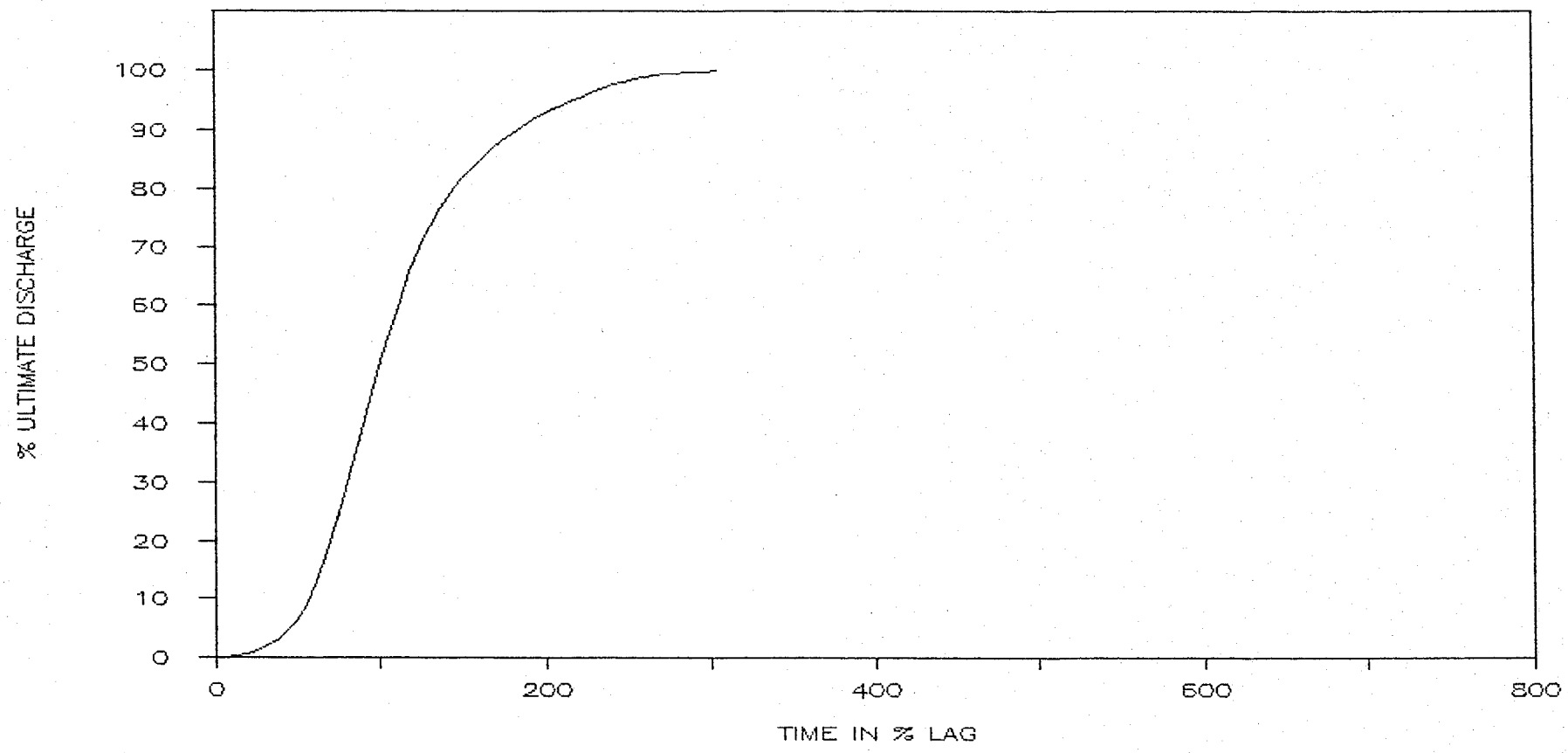
11-2.03 WALNUT GULCH WATERSHED 63.011

27 JULY 1964



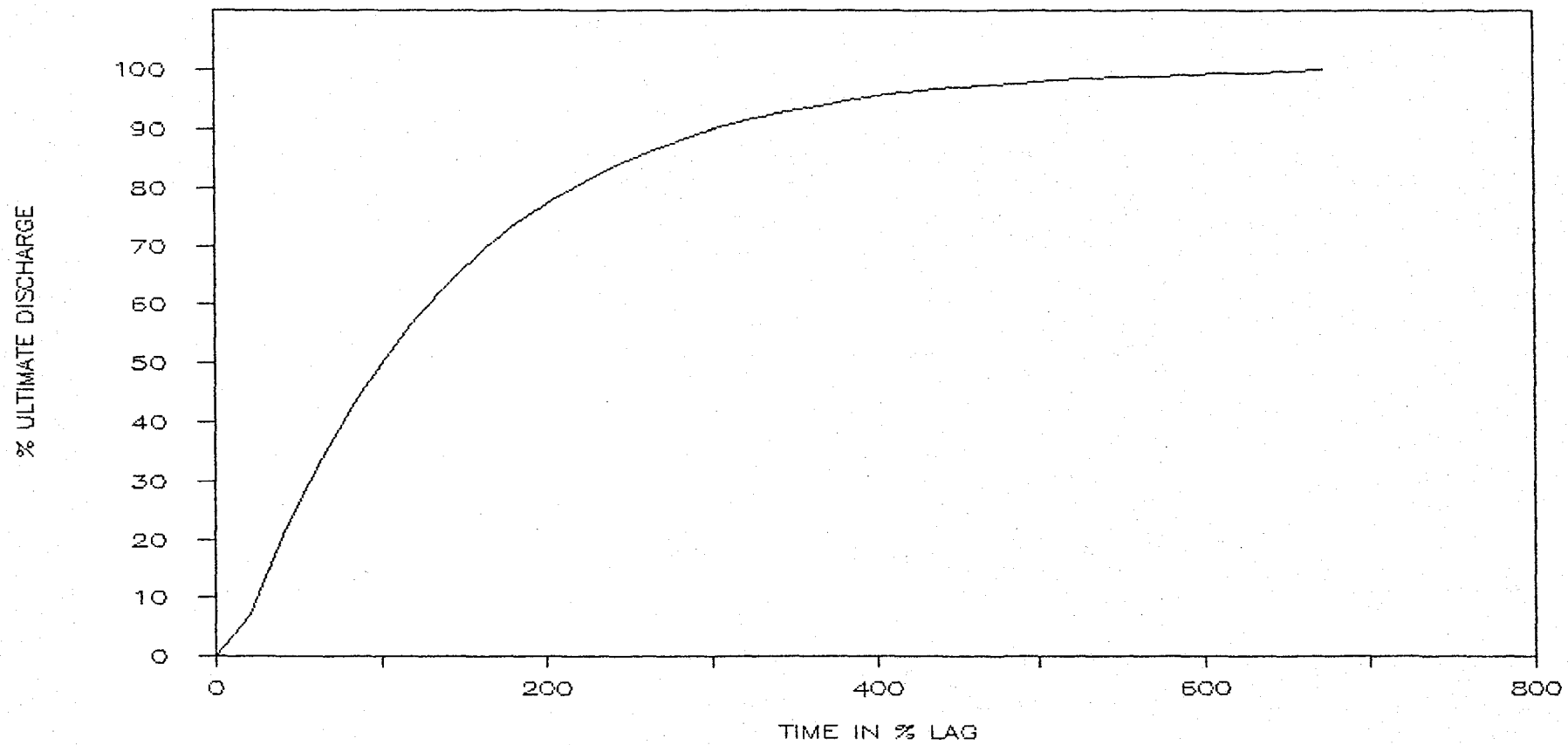
15-1.02 WALNUT GULCH WATERSHED 63.015

6 SEPTEMBER 1976



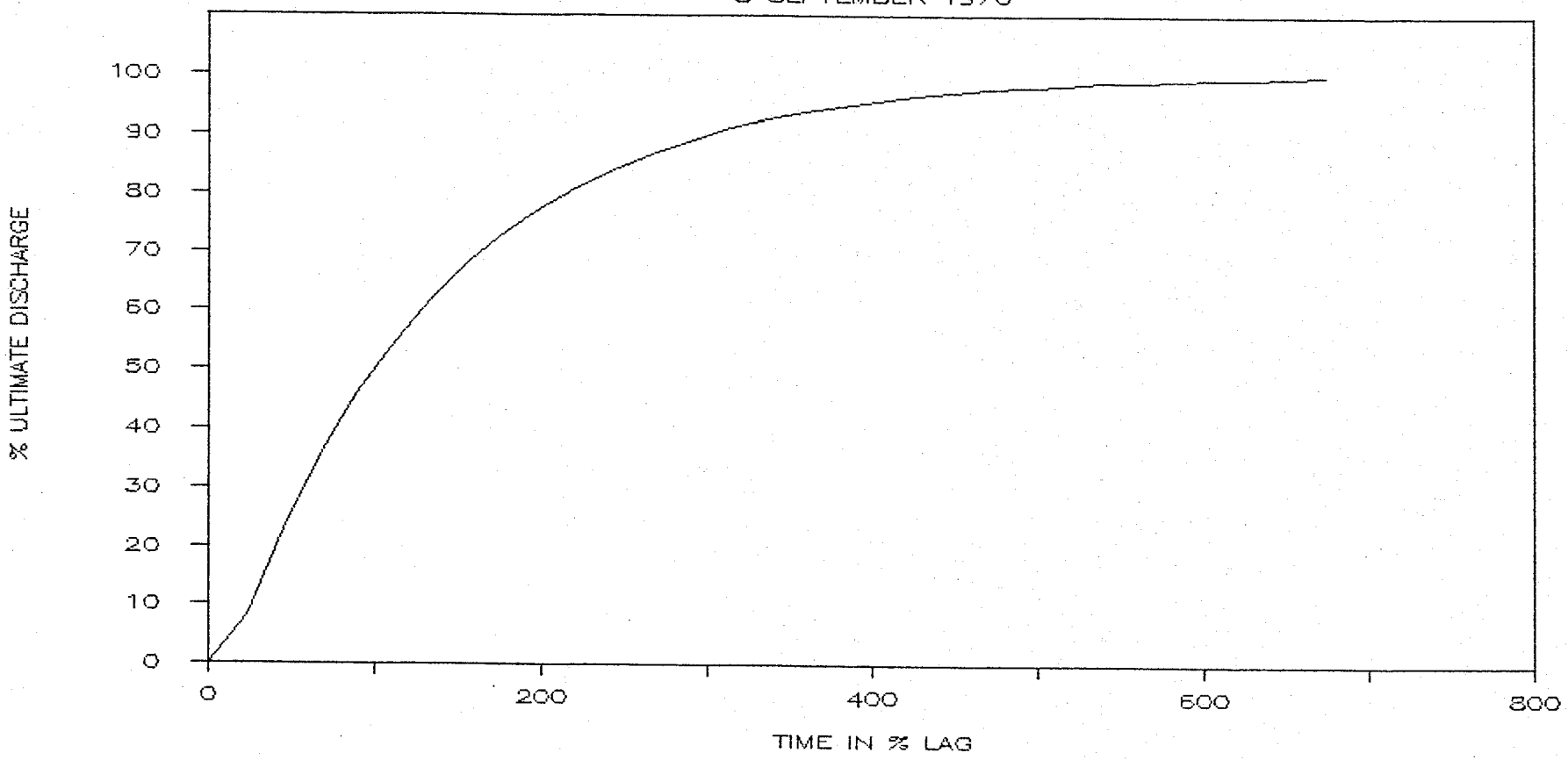
103-1.01 WALNUT GULCH WATERSHED 63.103

10 AUGUST 1971



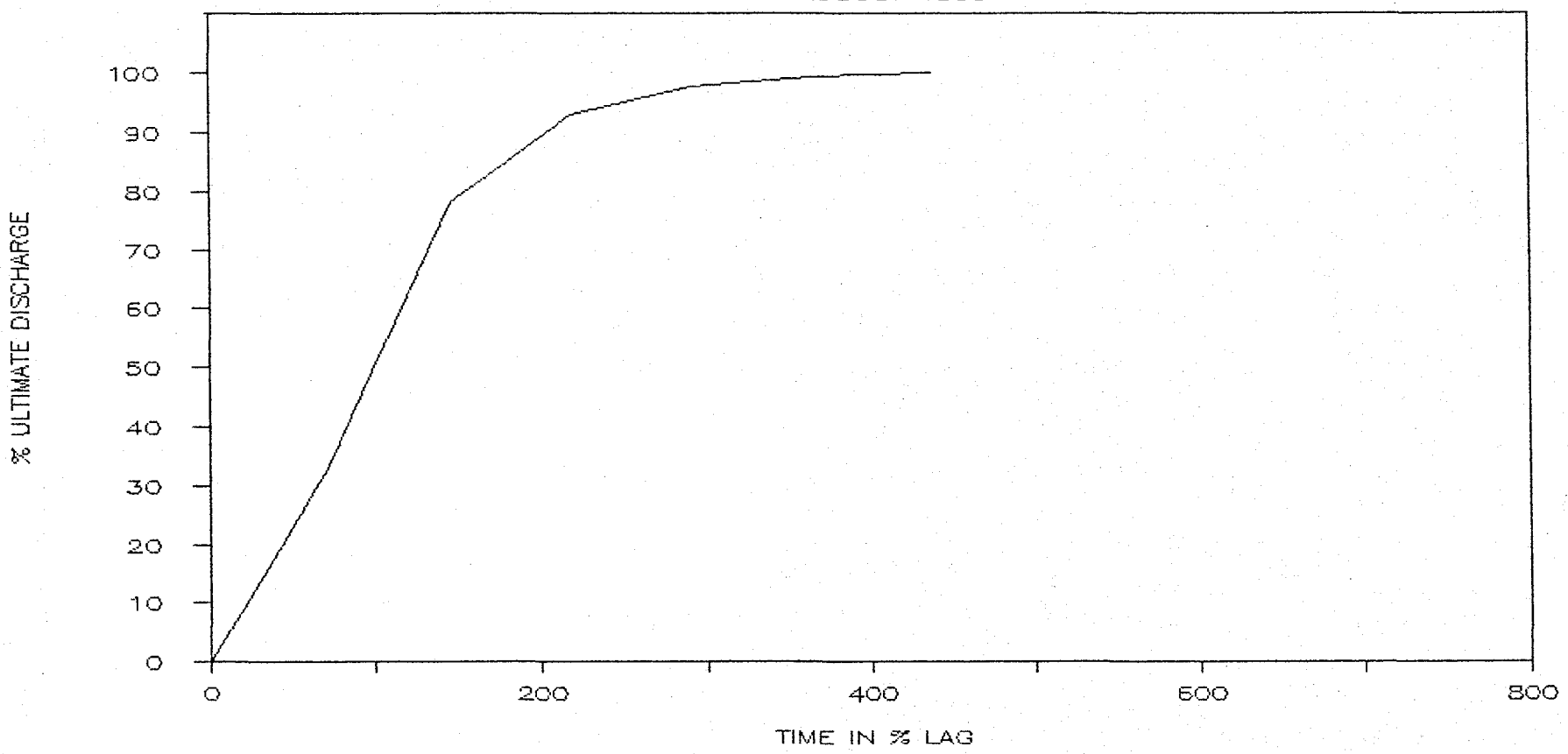
103-2.01 WALNUT GULCH WATERSHED 63.103

8 SEPTEMBER 1970



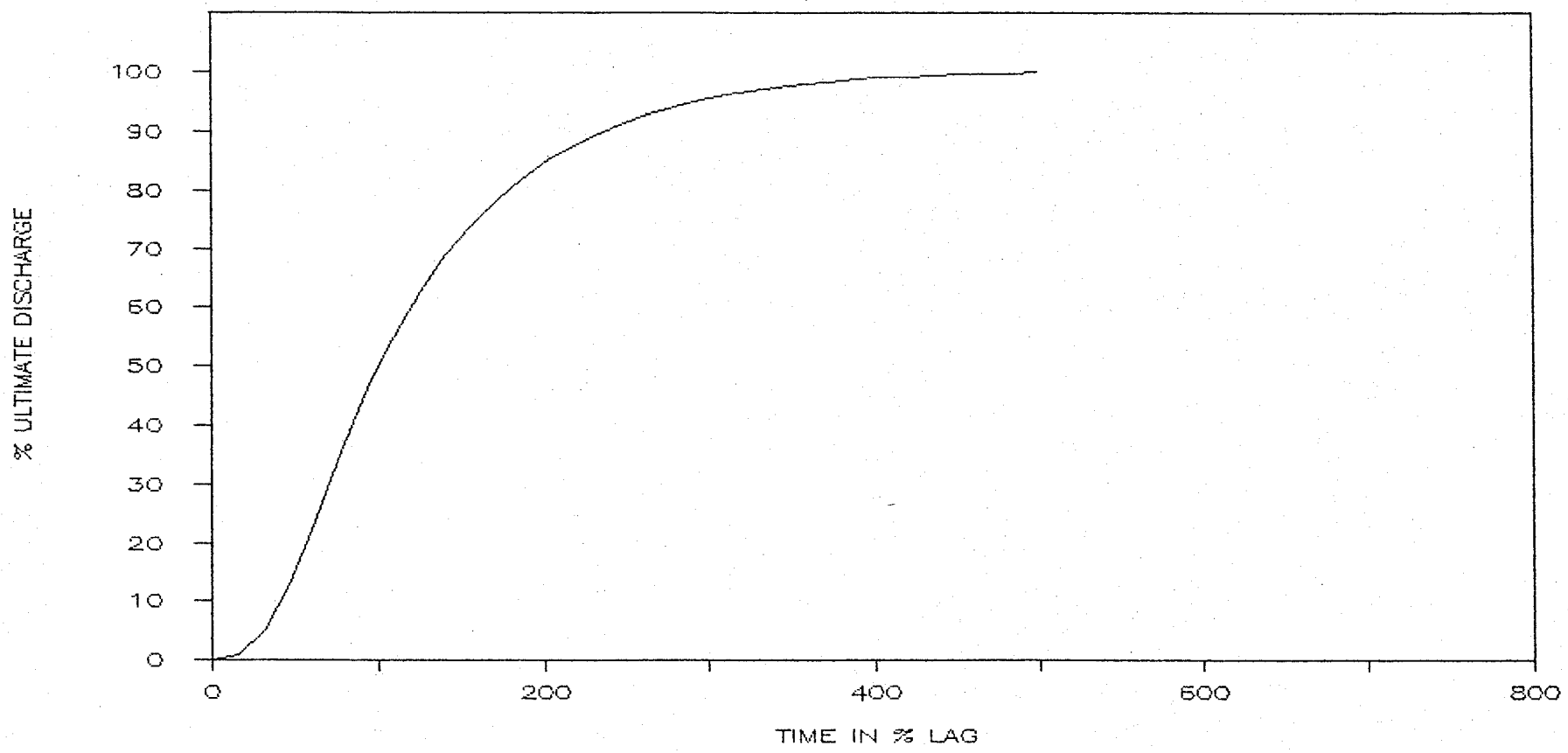
111-1.01 WALNUT GULCH WATERSHED 63.111

19 AUGUST 1963



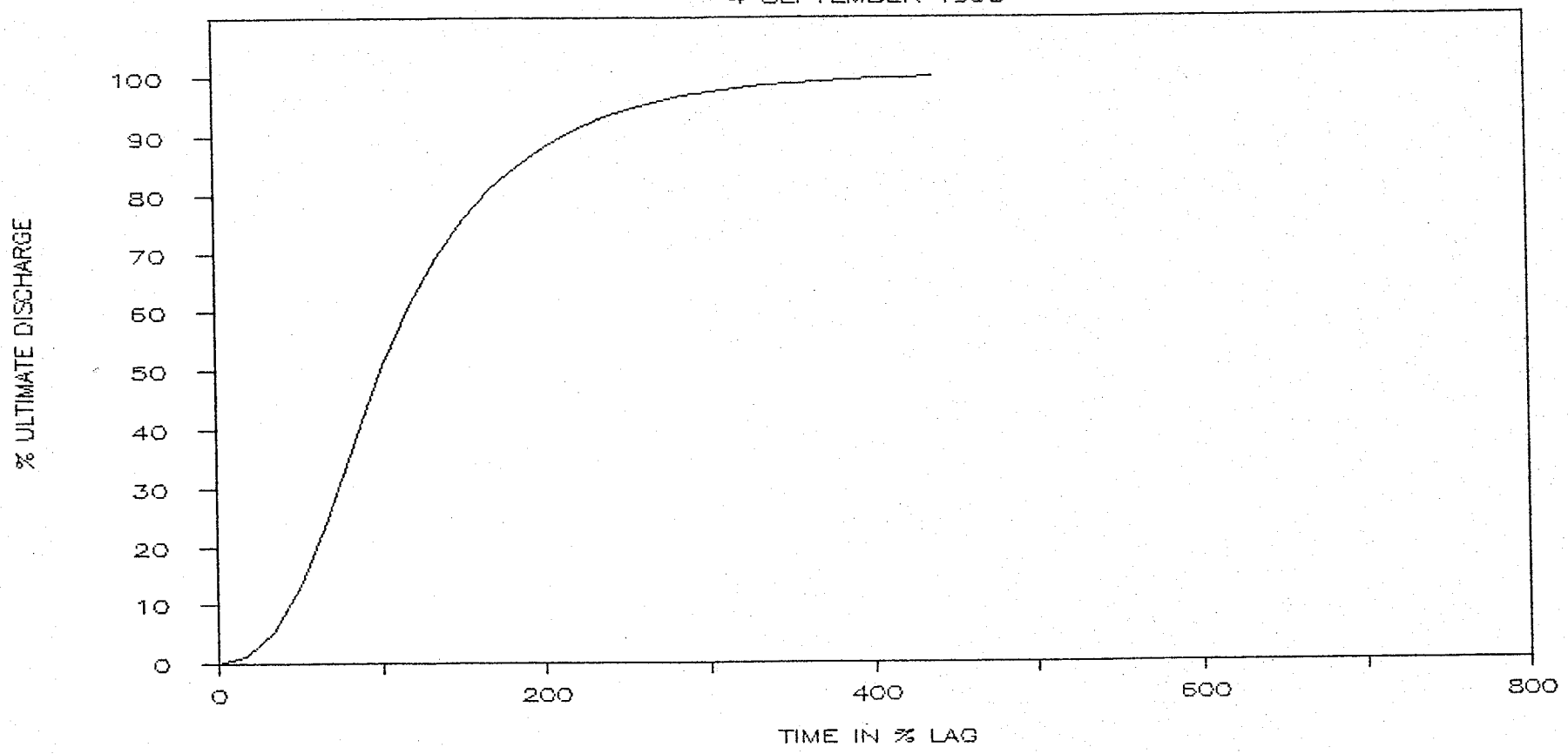
111-2.01 WALNUT GULCH WATERSHED 63.111

11 SEPTEMBER 1964



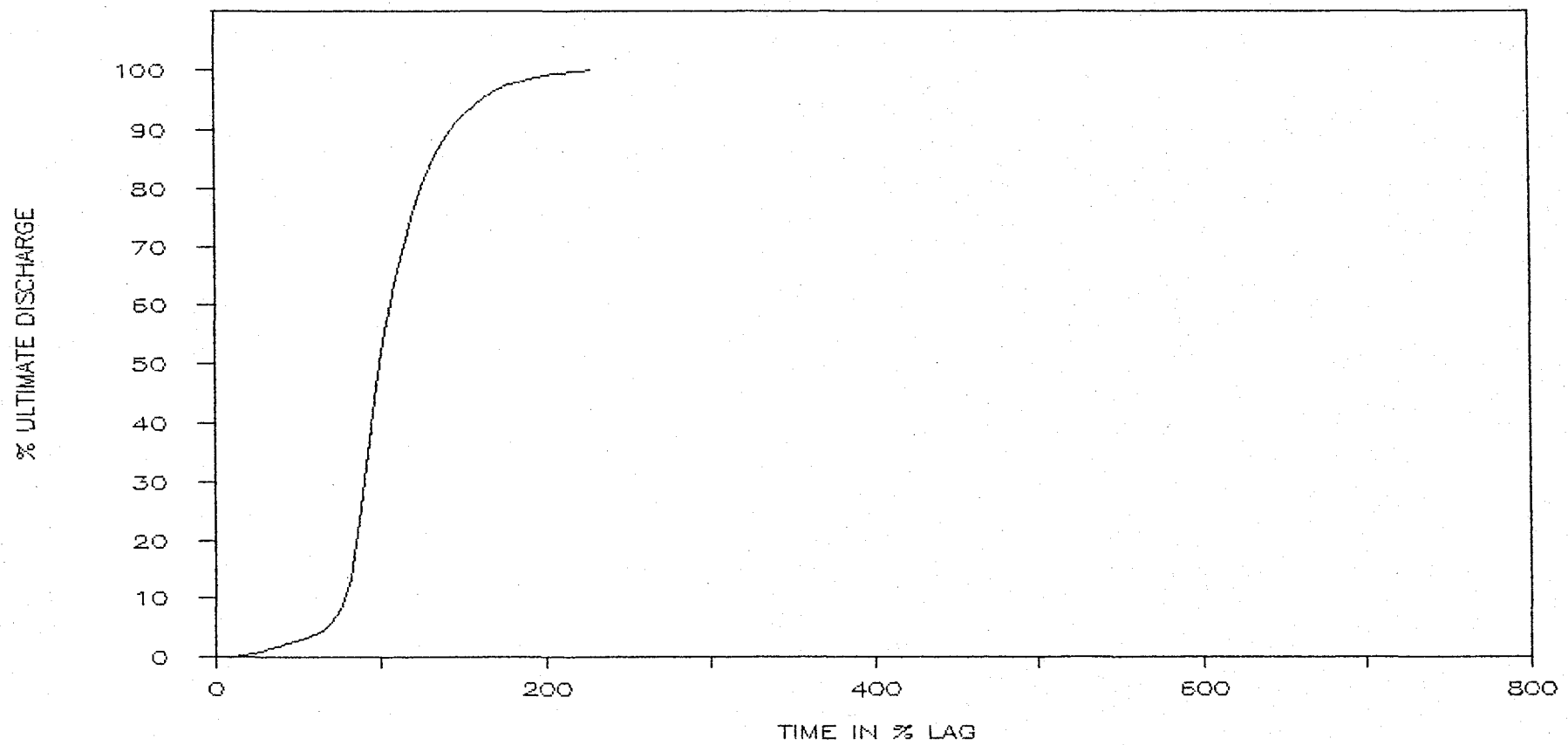
111-3.01 WALNUT GULCH WATERSHED 63.111

4 SEPTEMBER 1965



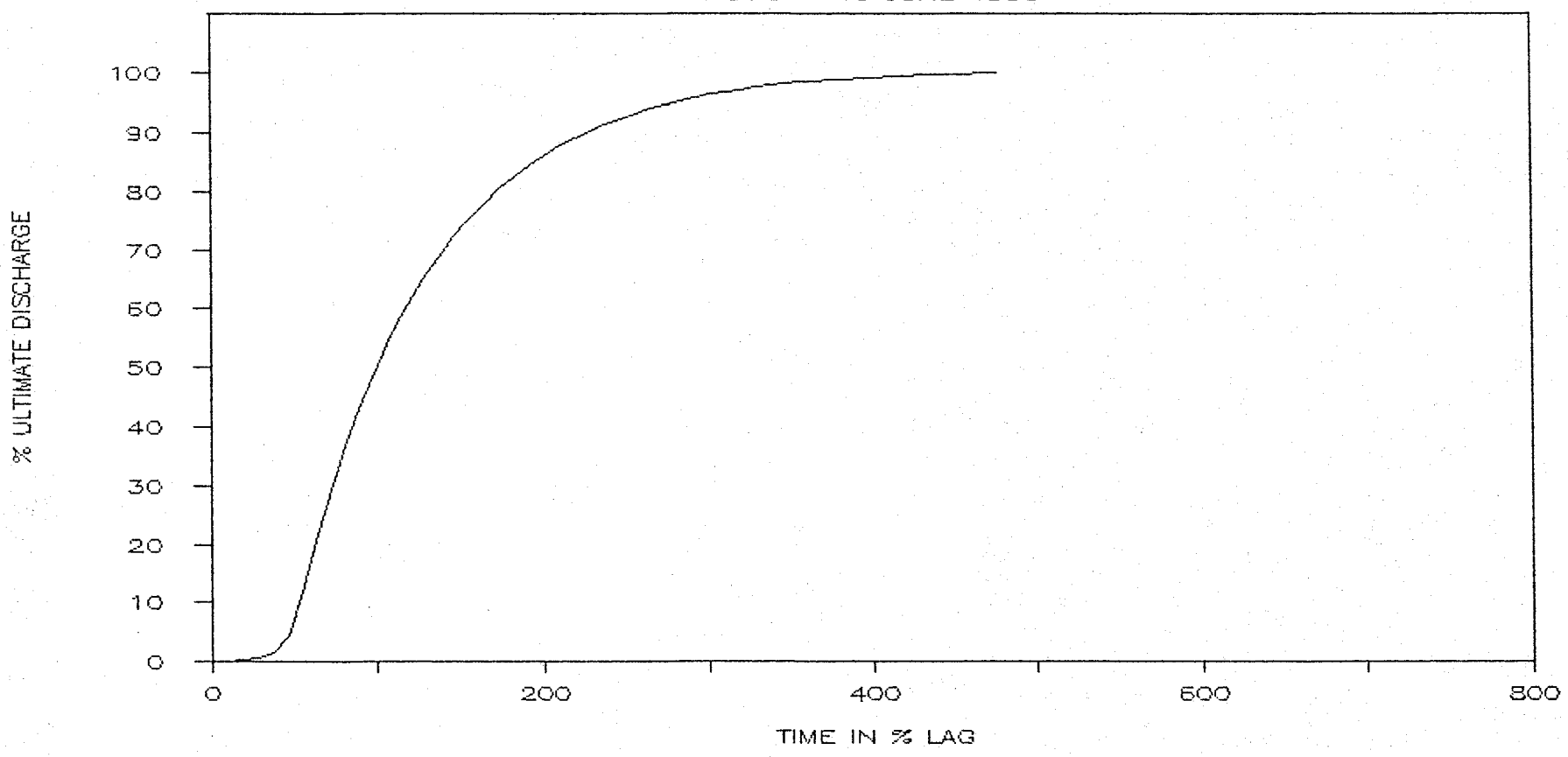
W. FK DRY CHEYENNE CK. AT UPPER STATION

WCU1 12 JUNE 1967



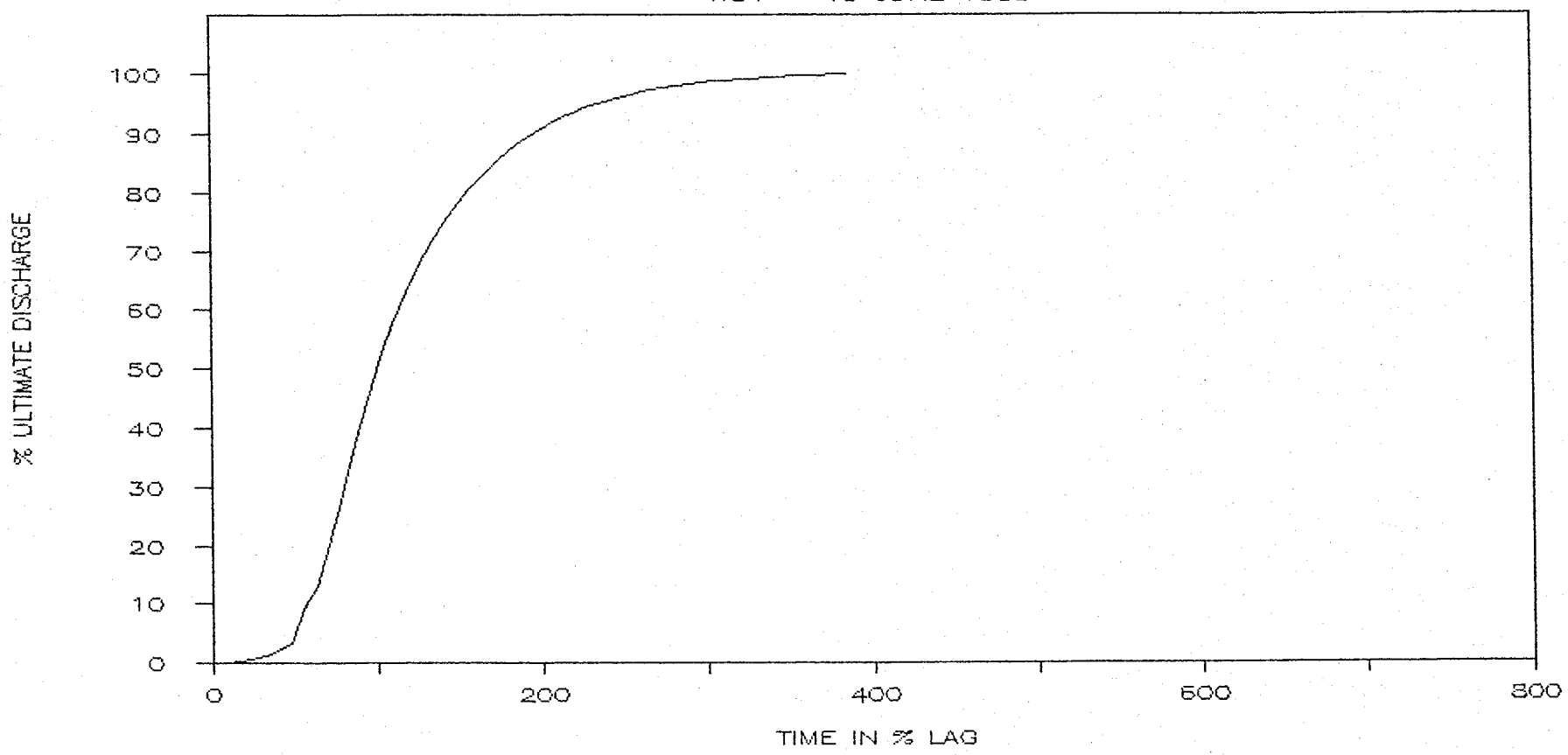
W. FK DRY CHEYENNE CK. AT UPPER STATION

WCU2 10 JUNE 1969



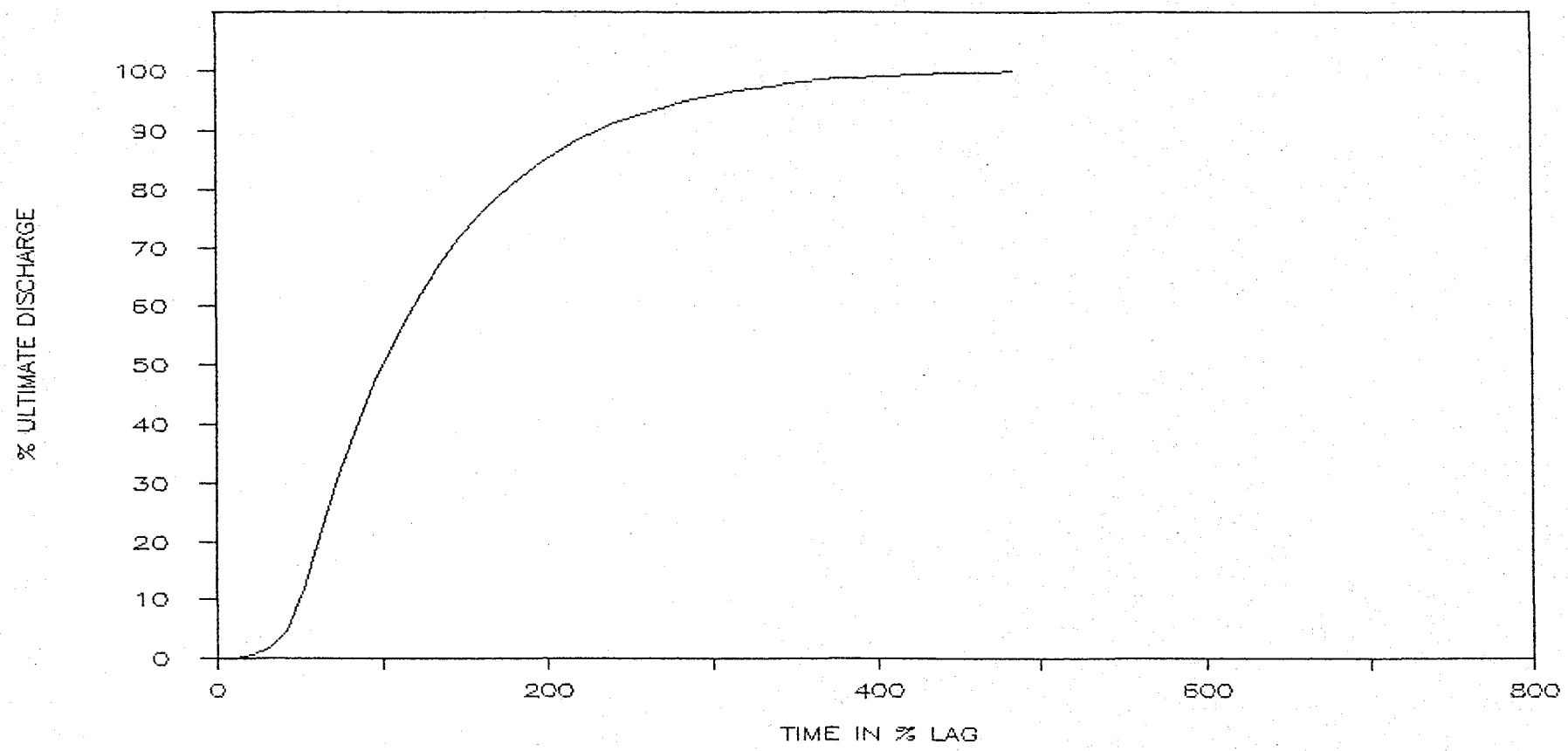
W FK DRY CHEYENNE CK TRIB NEAR RIVERTON

WC1 10 JUNE 1969



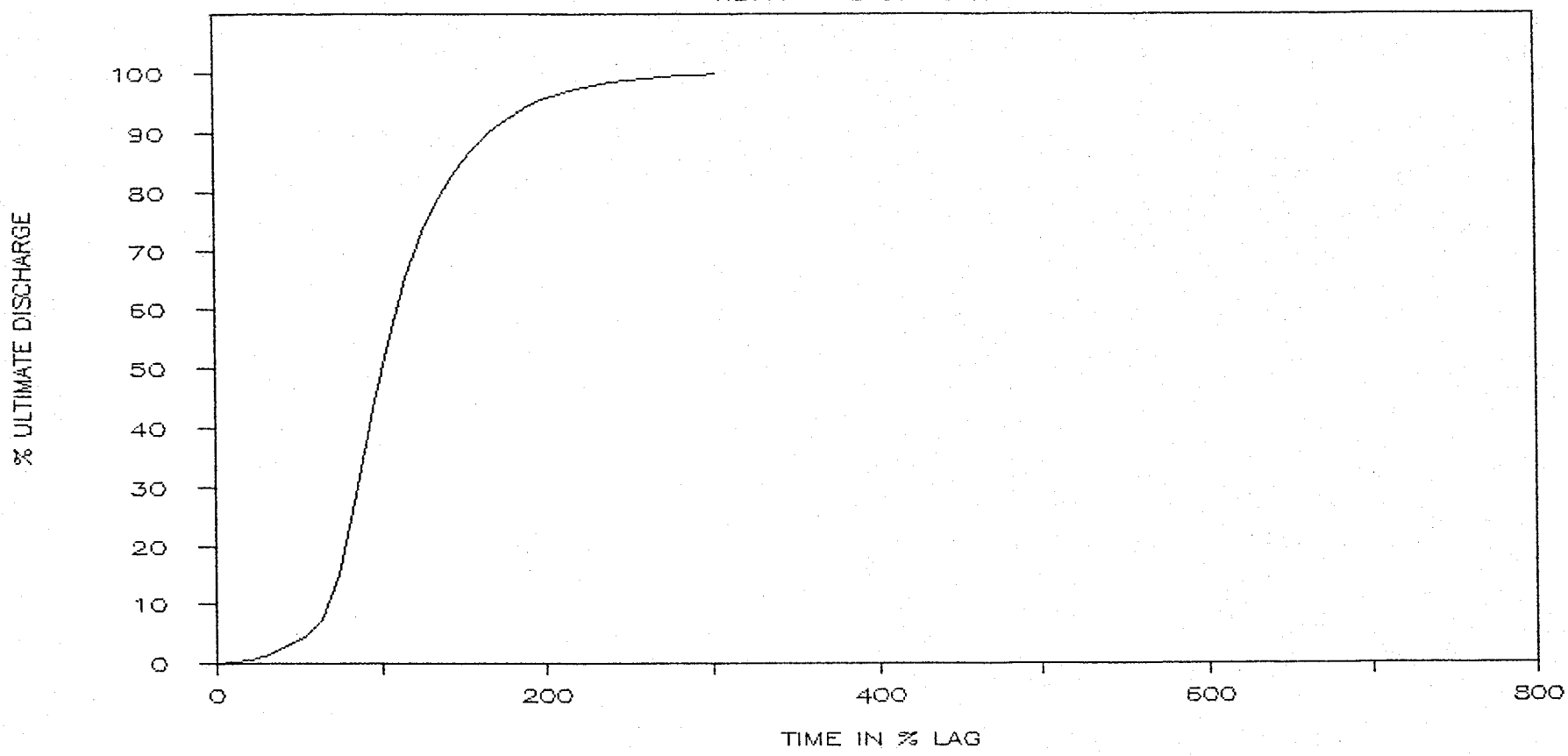
W FK DRY CHEYENNE CK TRIB NEAR RIVERTON

WC2 5 JUNE 1972



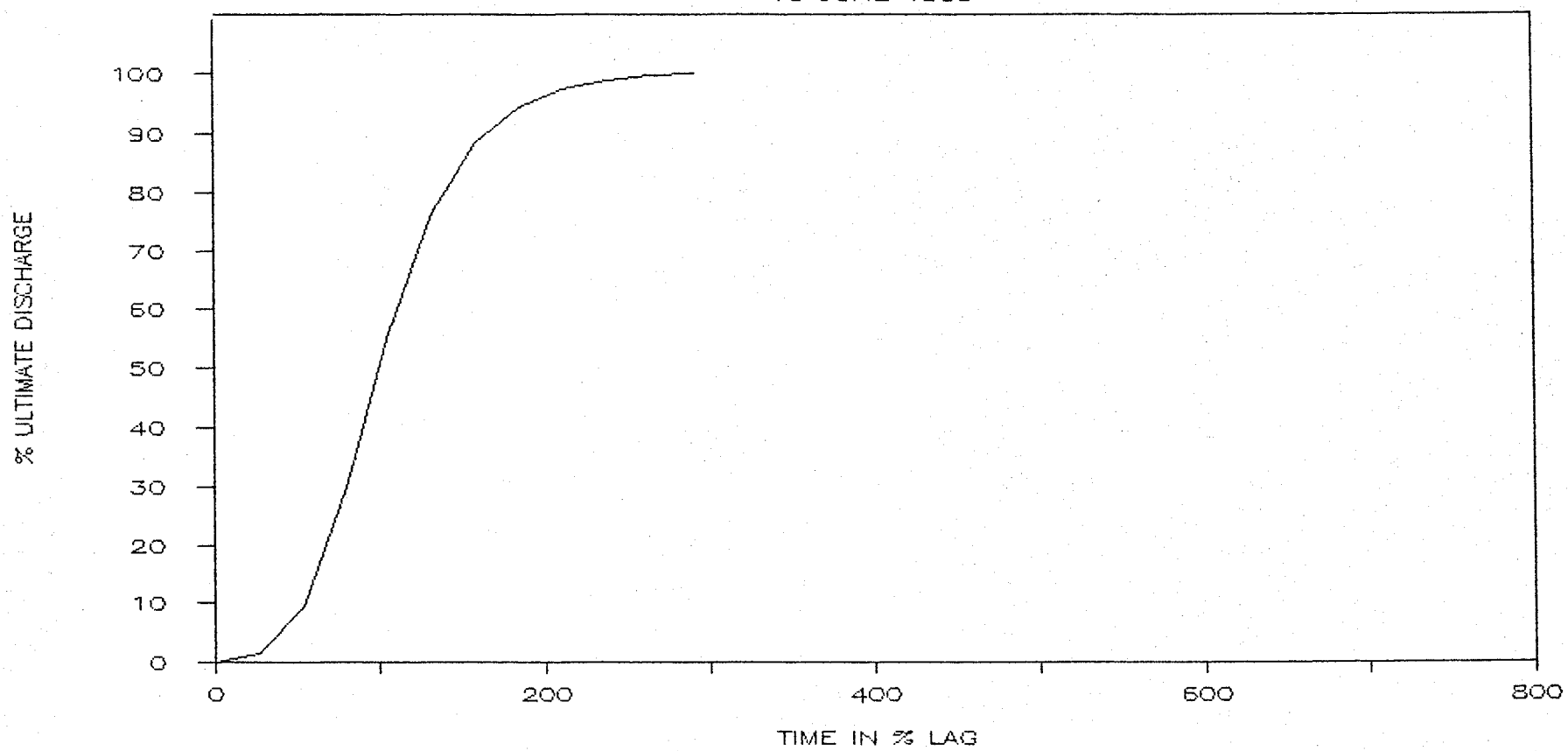
DEAD HORSE CREEK TRIB. NEAR MIDWEST

WDH1 3 JUNE 1972



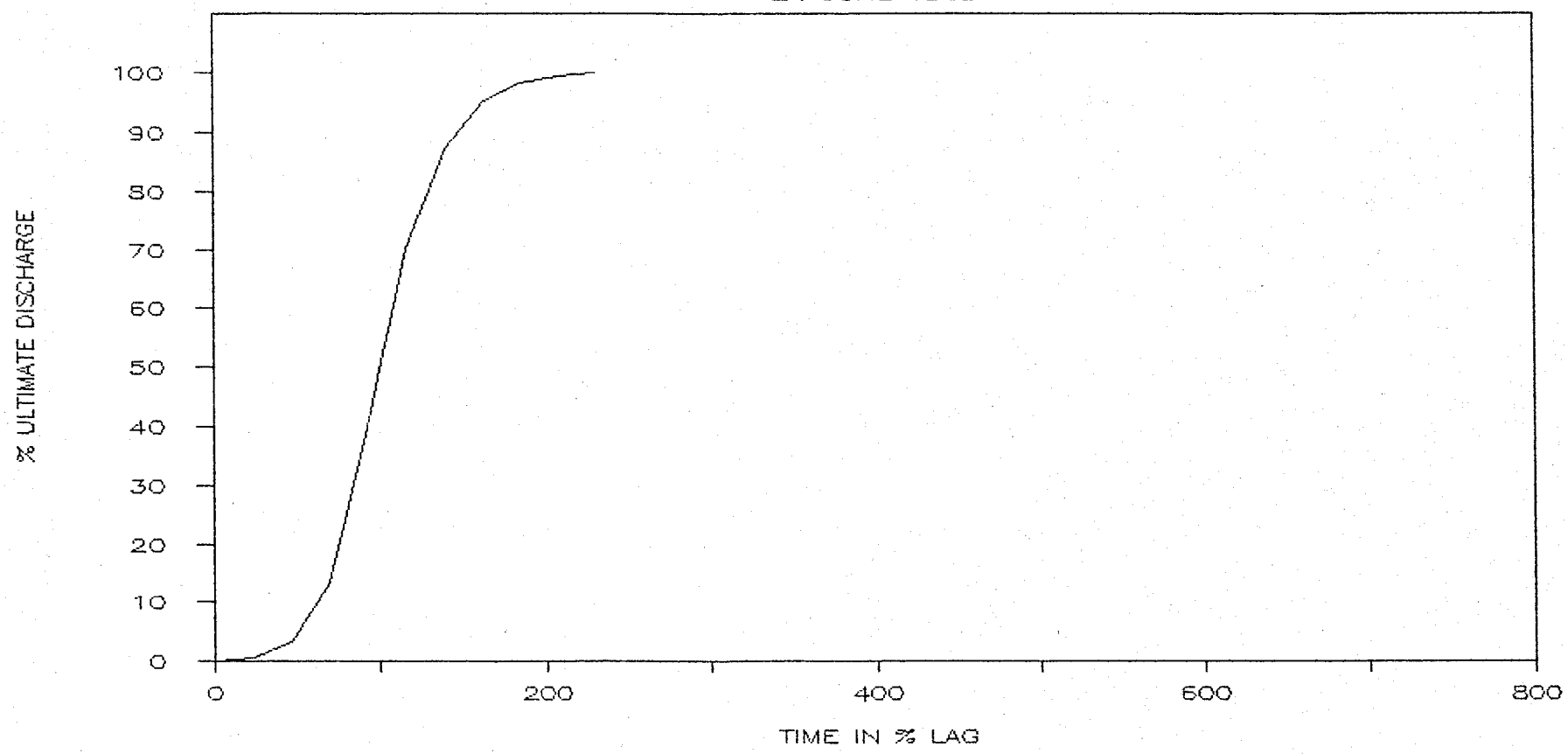
WET1 EAST TEAPOT CREEK NR. EDGERTON

10 JUNE 1965



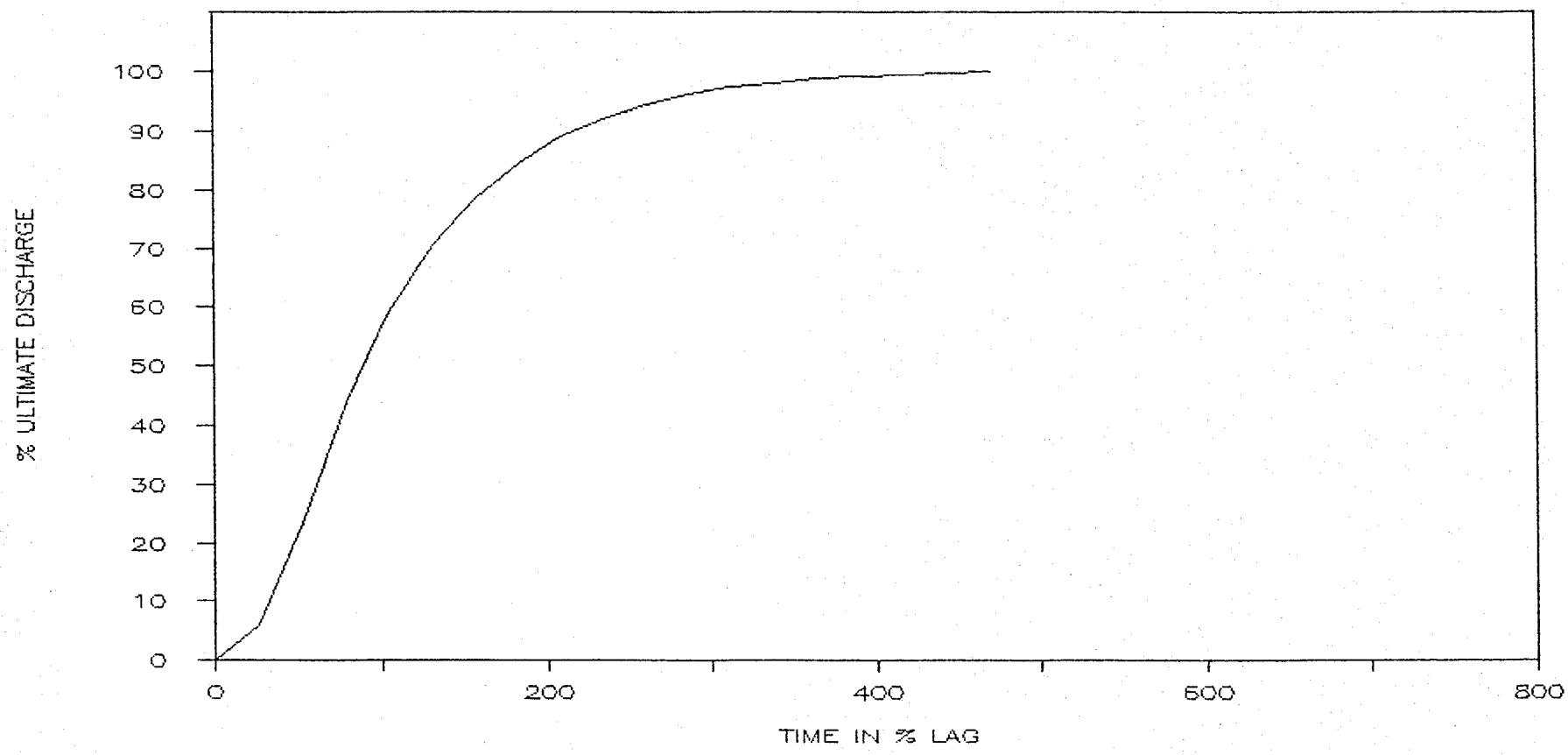
WD1 DUGOUT CREEK NEAR MIDWEST

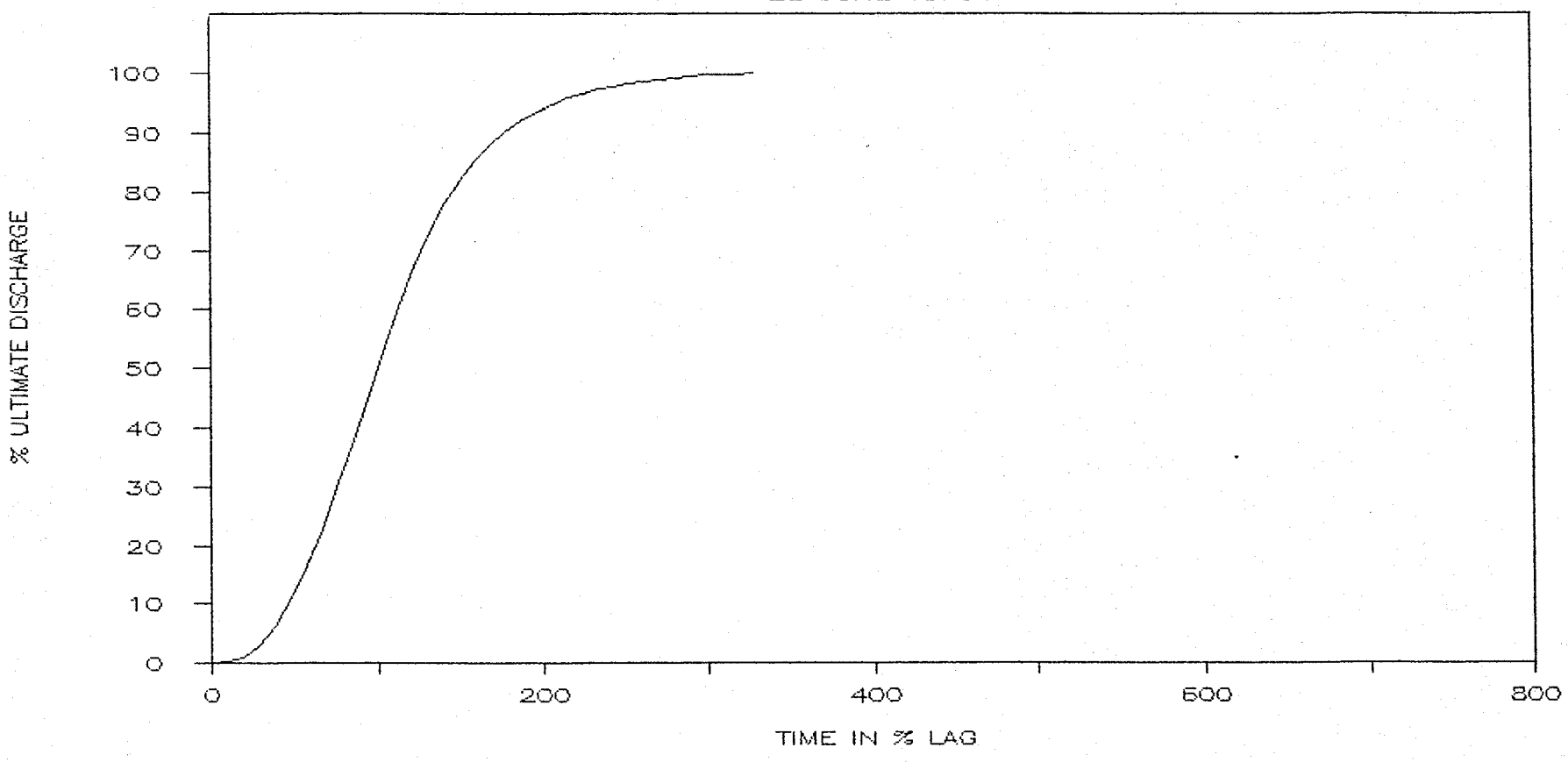
24 JUNE 1965



HEADGATE DRAW NEAR BUFFALO WYOMING

WHD1 16 JULY 1969



WMB1 MEDICINE BOW RIVER NEAR HANNA

25 JUNE 1973