equivalent S* loss parameter by the relationship following the Soil Conservation procedure (Ref. 14).

$$S^* = \frac{1000}{CN} - 10$$

Based on the experience of the author of the model, the foregoing S* magnitudes were plotted at the API values corresponding to the 15, 50 and 85 percent points. Values of SMIN and SMAX were subsequently established by graphical curve extension and Sk the, curve slope, was computed from the exponential equation relating this parameter to S*, SMIN and SMAX.

An example of the S* versus API relationship derived for the Boyne River catchment to Earl Rowe Park is shown in Figure 3.2. In this Figure an S* versus API relationship is derived for the A, B, C soil types and land use covers in addition to the aggregate value of S* for the total catchment area. The SK value derived in this case was 0.11.

3.2.3.5 Routing Reaches and Reservoirs

To simulate the routing characteristics of the basins the model includes 103 routing reaches and 2 routing reservoirs. The reach information was obtained from the survey of 30 representative channel cross-sections (Figure 2.2) in conjunction with overbank information supplemented from 1:10,000 mapping and 1:2,000 mapping from earlier flood plain mapping studies.

Two routing reservoirs were included to simulate the outflows from Little Lake on the Willow Creek system and Earl Rowe Dam on the Boyne River system.

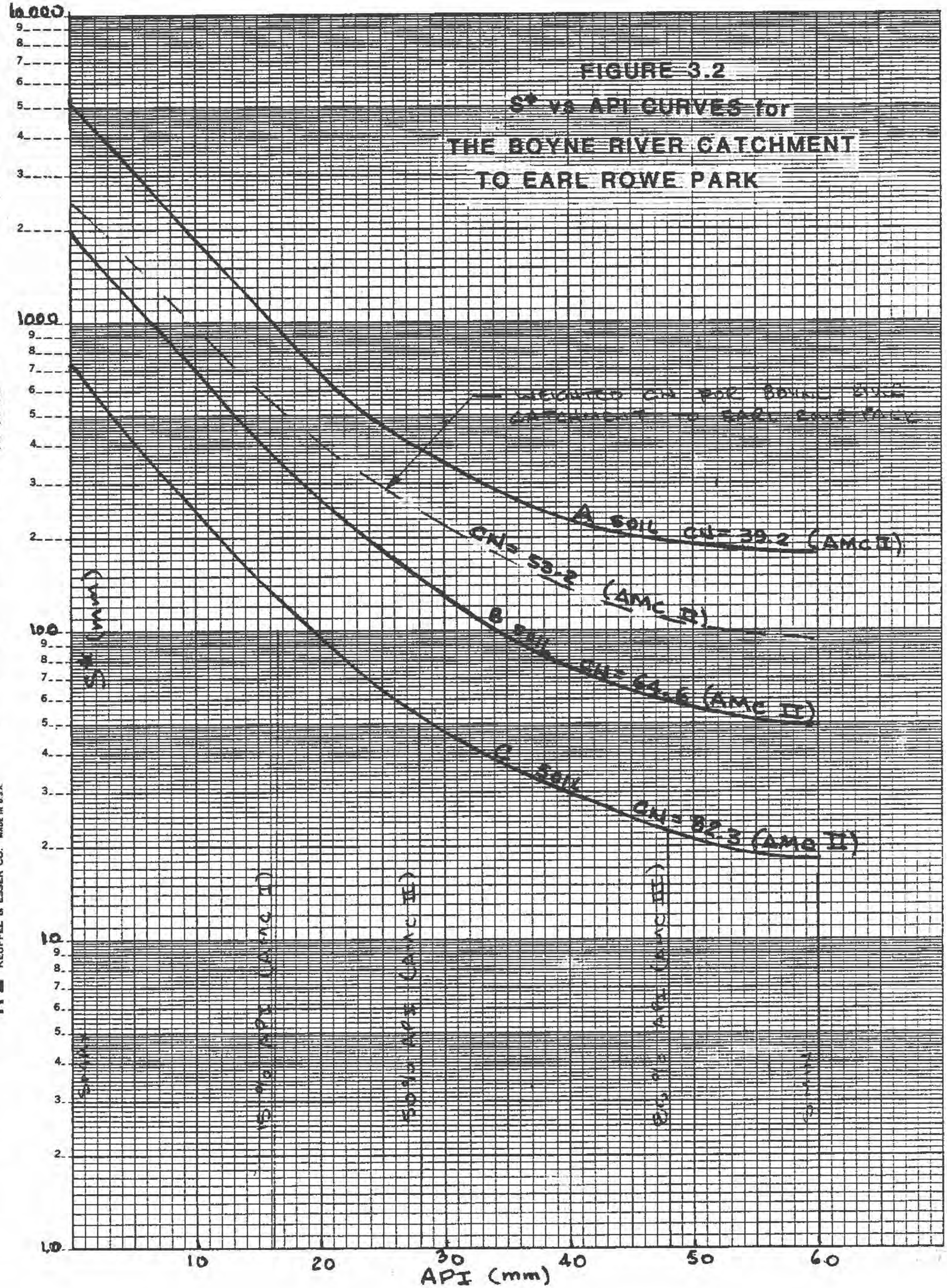


FIGURE 3.2
S* vs API CURVES for
THE BOYNE RIVER CATCHMENT
TO EARL ROWE PARK
A SOIL CN=39.2 (AMC II)
CN=53.2 (AMC II)
B SOIL CN=64.6 (AMC II)
C SOIL CN=82.3 (AMC II)
15% API (AMC I)
50% API (AMC II)
API (AMC III)
S* (mm)
API (mm)
10,000
1000
100
10
1.0
10
20
30
40
50
60
K+E KEUFFEL & ESSER CO. MADE IN U.S.A.

Information for Earl Rowe Dam was obtained from the Ministry of Natural Resources, Central Region while similar information for Little Lake was provided by the Ministry of Natural Resources, Huronia District.

3.2.4 Model Calibration

3.2.4.1 General

As outlined in Section 3.1.2, hourly streamflow data for the 1975-1984 period was obtained from Water Survey of Canada and the Ontario Ministry of the Environment. It was found desirable to calibrate the QUALHYMO Model for catchment areas exhibiting a predominant type of hydrologic soils before applying the results to ungauged sub-catchments.

From the hydrologic soil cover complexes presented in Appendix C for the various A, B, and C soil types, Tables 3.4 was prepared. It is evident that Willow Creek exhibits predominantly B soil; Mad River, B-C soil; Pine River, A-B soil; Boyne River, A-B soil and Beeton Creek a mixture of A, B, C soils. From the above results, it was decided to calibrate the following catchment areas: Willow Creek above Little Lake, Mad River near Glencairn and Boyne River at Earl Rowe Park. These models were calibrated for specific summer and spring events during the 1980-1984 period. Additional calibration of the Nottawasaga River basin to Baxter and Beeton Creek at Tottenham and the Pine River to Everett was carried out subsequently for a summer event (July 1980) to check the model accuracy for mixed soil conditions.

Lumped models for the Mad River near Glencairn, Pine River near Everett, Nottawasaga River and Willow Creek above Little Lake are listed in Appendix E along with the appropriate precipitation station used as input to each lumped sub-model (Table 3.5).

The lumped model for the Nottawasaga River at Baxter gauge consisted of lumped sub-models for Beeton Creek, Bailey Creek, Upper Nottawasaga River, Innisfil Creek, Boyne River and local drainage areas. Channel routing was

TABLE 3.4

HYDROLOGIC SOIL COMPONENT FOR CATCHMENT AREA INDICATED

	Soil Group										
	A			B			C				
Catchment	Area (km²)	%	CN	Area (km²)	%	CN	Area (km²)	%	CN	Total Area (km²)	Weighted CN
Willow Creek above Little Lake	7.4	7.8	40.1	87.5	92.2	65.4	-	-	-	94.9	63.5
Mad River near Glencairn	31.3	10.3	39	171.9	56.7	63	99.9	33.0	72.4	303.1	64.0
Pine River near Everett	95.6	47.1	26.3	70.0	34.5	61.3	37.4	18.4	69.3	203.0	45.7
Boyne River at Earl Rowe Park	101.3	48.9	39.4	88.2	42.6	66	17.5	8.5	82.1	207.1	54.4
Beeton Creek near Beeton	18.3	26.4	45.3	31.2	45.1	62.2	19.7	28.5	69.0	69.2	59.6

Note: Antecedent Moisture Condition II used for CN value

TABLE 3.5

PRECIPITATION STATIONS USED IN QUALHYMO LUMPED MODELS

River System	Daily Precipitation Station	Hourly Precipitation Station	6 Hourly Precipitation Station
Willow Creek	Shanty Bay	Barrie Orillia Bolton Maple Grand Valley Mt. Forest Fergus	Mt. Forest
Mad River	Redickville	Grand Valley Mt. Forest Fergus Barrie Bolton Maple Orillia	Mt. Forest
Boyne River Pine River	Shelbourne	Grand Valley Mt. Forest Fergus Bolton Maple Barrie Orillia	Mt. Forest
Beeton/Bailey Creeks	Beeton	Bolton Barrie Maple Grand Valley Mt. Forest Fergus Orillia	Mt. Forest
Upper Nottawasaga River	Orangeville	Grand Valley Fergus Bolton Maple Mt. Forest Barrie Orillia	Mt. Forest

TABLE 3.5 (cont'd)

PRECIPITATION STATIONS USED IN QUALHYMO LUMPED MODELS

River System	Daily Precipitation Station	Hourly Precipitation Station	6 Hourly Precipitation Station
Innisfil Creek	Cookstown	Barrie Bolton Orillia Maple Grand Valley Mt. Forest Fergus	Mt. Forest
Mid-Nottawasaga River and Lower Boyne River	Alliston	Bolton Barrie Maple Grand River Mt. Forest Fergus Orillia	Mt. Forest

also included for each of the lumped models and an appropriate precipitation station was selected for precipitation input. The daily station selected for each lumped model and the corresponding hourly stations used to distribute precipitation is presented in Table 3.5.

As outlined in Section 3.2.3.1, a discretized QUALHYMO Model was set-up for all sub-catchment areas within the N.V.C.A. However, in order to establish initial model calibration parameters, a single lumped model was set-up for the Willow Creek, Mad River, Boyne River and Pine River catchment areas to their respective gauging stations. The primary purpose of this exercise was to adjust model parameters to obtain volume of runoff and peaks in close agreement to the observed.

For the Boyne River, the dam and reservoir upstream of the gauge was included in the modelling to account for its routing effect. The discharge characteristics for the dam and reservoir used in the model were obtained from MNR as noted in Section 3.2.3.5 while the stage - storage relationship for the reservoir was developed during the study. This information was provided to the Authority as part of the project files.

3.2.4.2 <u>Lumped Models</u>

3.2.4.2.1 <u>General</u>

Procedures outlined in Section 3.2.3.4 were used to estimate values of SMIN, SMAX and Sk for the lumped models of the Boyne, Pine and Mad Rivers and Willow Creek. The time to peak (tp) and recession constant (k) for each catchment area was computed using the William's empirical equations from the HYMO User Manual. Values of these parameters are given in Appendix H. The various parameters established are presented in Table 3.6. A plot of S*

TABLE 3.6

QUALHYMO PARAMETERS FOR CATCHMENT AREAS INDICATED

Catchment	Drainage Area (Km^2)	Time to Peak (TP) Hours	Recession Constant (K) Hours	Weighted CN	SMIN (mm)	SMAX (mm)	SK
Mad River near Glencairn	303.1	9.0	7.8	64	50	2000	0.11
Boyne River at Earl Rowe Park	207.1	13.4	12.2	54.4	95	2400	0.11
Willow Creek above Little Lake	94.9	7.4	10.5	63.5	50	2000	0.11
Pine River near Glencairn	203.0	12.7	9.6	45.7	111	3010	0.11
Beeton Creek near Tottenham	69.2	6.8	6.4	59.6	63	2085	0.11

versus API for the Mad River, Boyne River and Willow Creek catchments is presented in Figure 3.3.

The QUALHYMO model was run for the Willow Creek for a five month period during the summer of 1980 to calibrate the base flow parameters. Using hourly rainfall data, a plot of hourly simulated and observed flows was obtained for the five month period. Adjustments were made to the various base flow parameters until good agreement was obtained.

The final values used for the various parameters are presented below:

SLOSK1	(Base flow recession constant) = 0.000002 mm/sec/mm
SLOSK2	(Base flow reduction factor) = 0.2
BASMIN	(Minimum base flow rate) = 0 m^3/s

The parameter SLOSK1 is considered most important in controlling the base flow magnitudes.

The model was calibrated separately for summer and spring events because of the different conditions involved. These investigations are discussed in Sections 3.2.4.2.2 and 3.2.4.2.3 respectively.

3.2.4.2.2 <u>Calibration of Summer Events</u>

Daily streamflow data were used to computer plot continuous hydrographs from 1975-1984. These plots were screened to identify high flow summer events. The summer events selected for calibration between 1980 and 1984 are shown in Table 3.7 together with the recorded flows and rainfall amount.

For the July 28, 1980 high flow event, the rainfall amount of 6.8 mm recorded at Redickville does not appear consistent with rainfall amounts recorded at nearby stations. Therefore, the rainfall from this station was disregarded. In conducting the calibration for each of the above events,

TABLE 3.7

CALIBRATION/VALIDATION FOR SUMMER EVENTS

Watercourse	Peak Flow (m^3/s) Date of Peak	Peak Flow (m^3/s) Observed	Peak Flow (m^3/s) Simulated	Observed Rainfall (mm) Rainfall Duration	Observed Rainfall (mm) Colling-wood	Observed Rainfall (mm) Redick-ville	Observed Rainfall (mm) Shelburne	Observed Rainfall (mm) Barrie	Observed Rainfall (mm) Shanty Bay
Mad River Near Glencairn	28 July 1980	34.8	34.7	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1
	15 June 1982	13.9	11.8	15-16 June 1982	47.7	37.8	29.2	33.3	36.2
	26 Sept. 1977	8.5	8.9	24-26 Sept. 1977	41.0	45.0	37.8	26.0	24.8
Willow Creek Above Little Lake	28 July 1980	23.9	23.8	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1
	16 June 1982	9.8	9.6	15-16 June 1982	47.7	37.8	29.2	33.3	36.2
Boyne River at Earl Rowe Park	29 July 1980	28.9	26.8	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1
Beeton Creek near Tottenham	29 July 1980	3.9	5.0	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1
Pine River near Everett	29 July 1980	21.7	26.8	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1
Nottawasaga River near Baxter	29 July 1980	66.7	96.6	26-28 July 1980	41.3	6.8[1]	32.2	47.0	50.1

[1] Anomaly in Rainfall Data - Not used for calibration

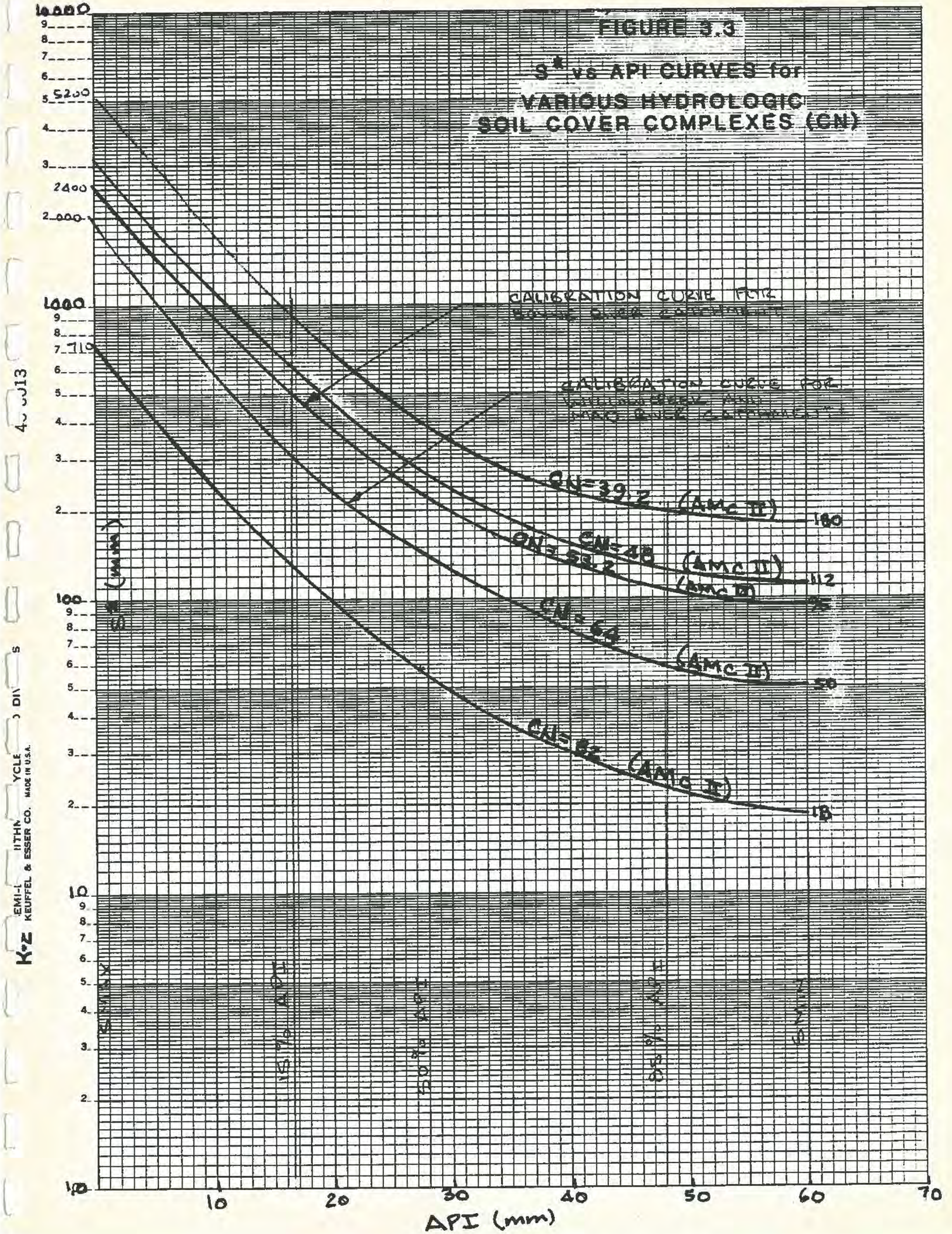
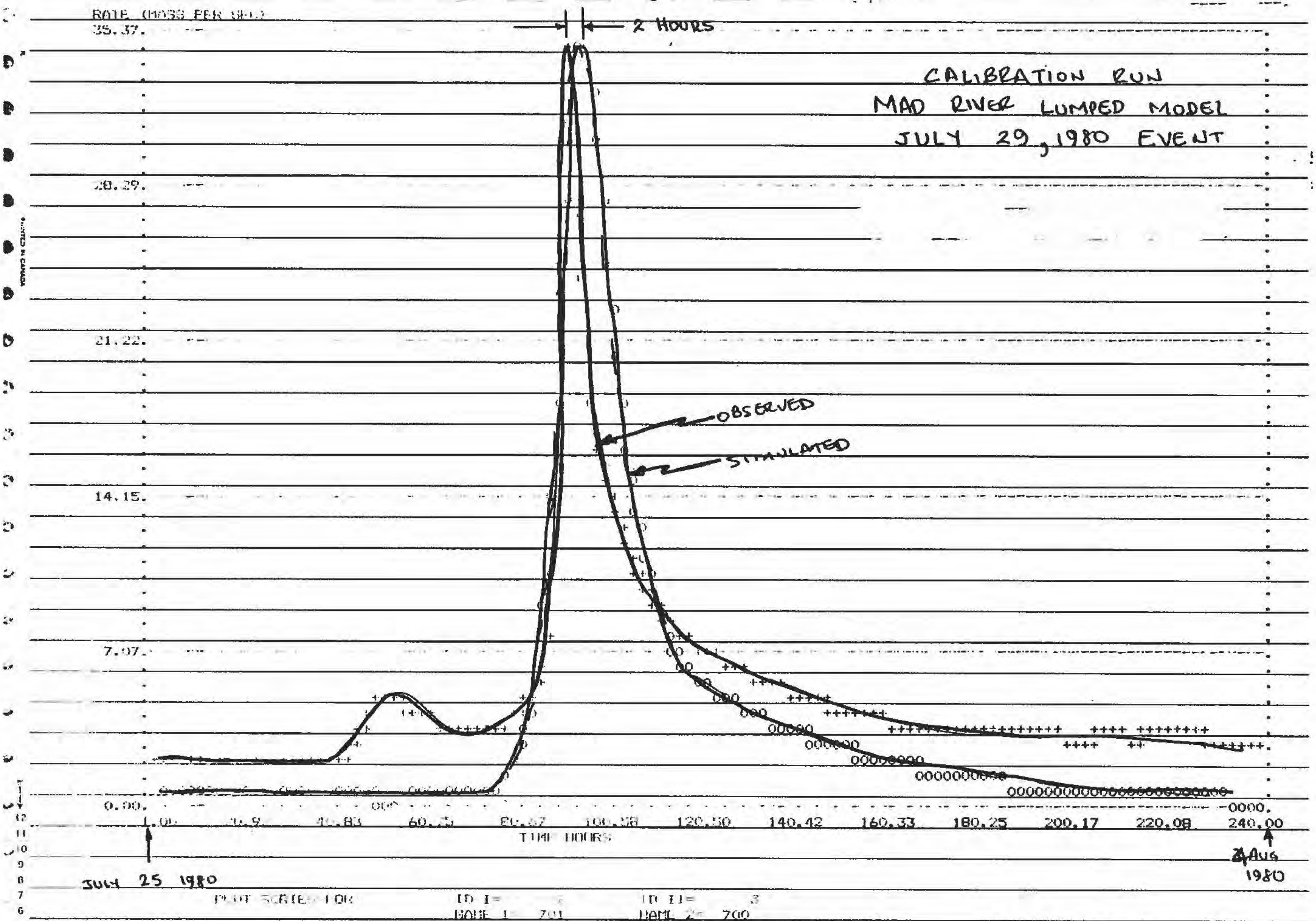
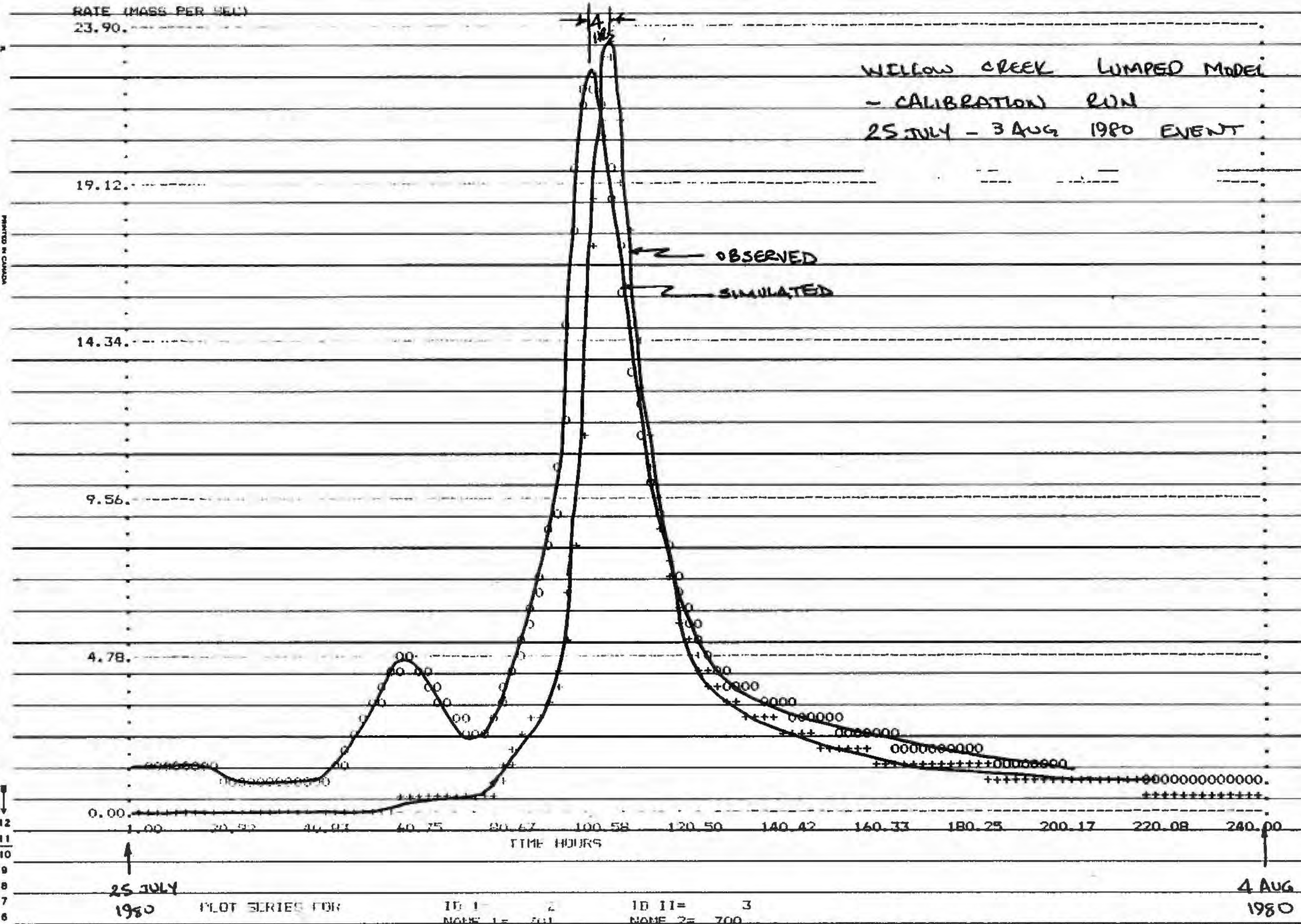


FIGURE 3.3
S* vs API CURVES for VARIOUS HYDROLOGIC SOIL COVER COMPLEXES (CN)
CALIBRATION CURVE FOR
CALIBRATION CURVE FOR
CN=39.2 (AMC II)
CN=48 (AMC II)
CN=53.2 (AMC II)
CN=64 (AMC II)
CN=82 (AMC II)
180
112
95
50
18
S* (mm)
API (mm)
15% API
50% API
85% API
5200
2400
2000
710
10000
1000
100
10
1.0
10
20
30
40
50
60
70



RATE (M**3 PER SEC)
35.37
28.29
21.22
14.15
7.07
0.00
2 HOURS
CALIBRATION RUN
MAD RIVER LUMPED MODEL
JULY 29, 1980 EVENT
OBSERVED
SIMULATED
1.00
40.83
60.75
120.50
140.42
160.33
180.25
200.17
220.08
240.00
TIME HOURS
JULY 25 1980
AUG 1980

Fig. 3.4 (a)



RATE (MASS PER SEC)
23.90
19.12
14.34
9.56
4.78
0.00
1.00
20.92
40.83
60.75
80.67
100.58
120.50
140.42
160.33
180.25
200.17
220.08
240.00
TIME HOURS
WILLOW CREEK LUMPED MODEL
- CALIBRATION RUN
25 JULY - 3 AUG 1980 EVENT
4 HRS
OBSERVED
SIMULATED
25 JULY 1980
4 AUG 1980
PLOT SERIES FOR
ID I= 2
ID II= 3
NAME 2= 700

Fig. 3.4 (c)

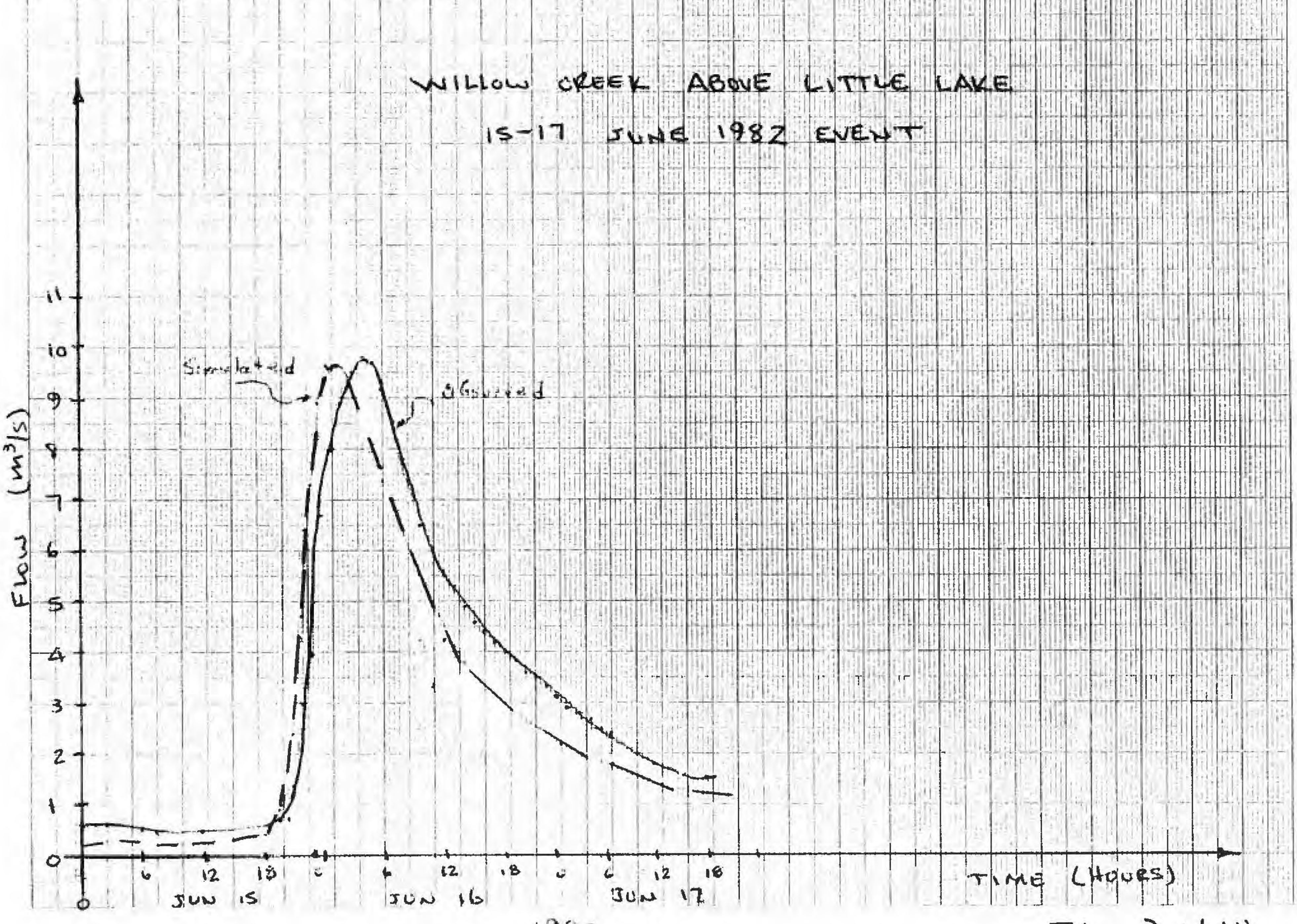

WILLOW CREEK ABOVE LITTLE LAKE
15-17 JUNE 1982 EVENT
Simulated
Observed
FLOW (m³/s)
0
1
2
3
4
5
6
7
8
9
10
11
6
12
18
0
6
12
18
0
6
12
18
JUN 15
JUN 16
JUN 17
TIME (HOURS)
1982

Fig 3.4(d)

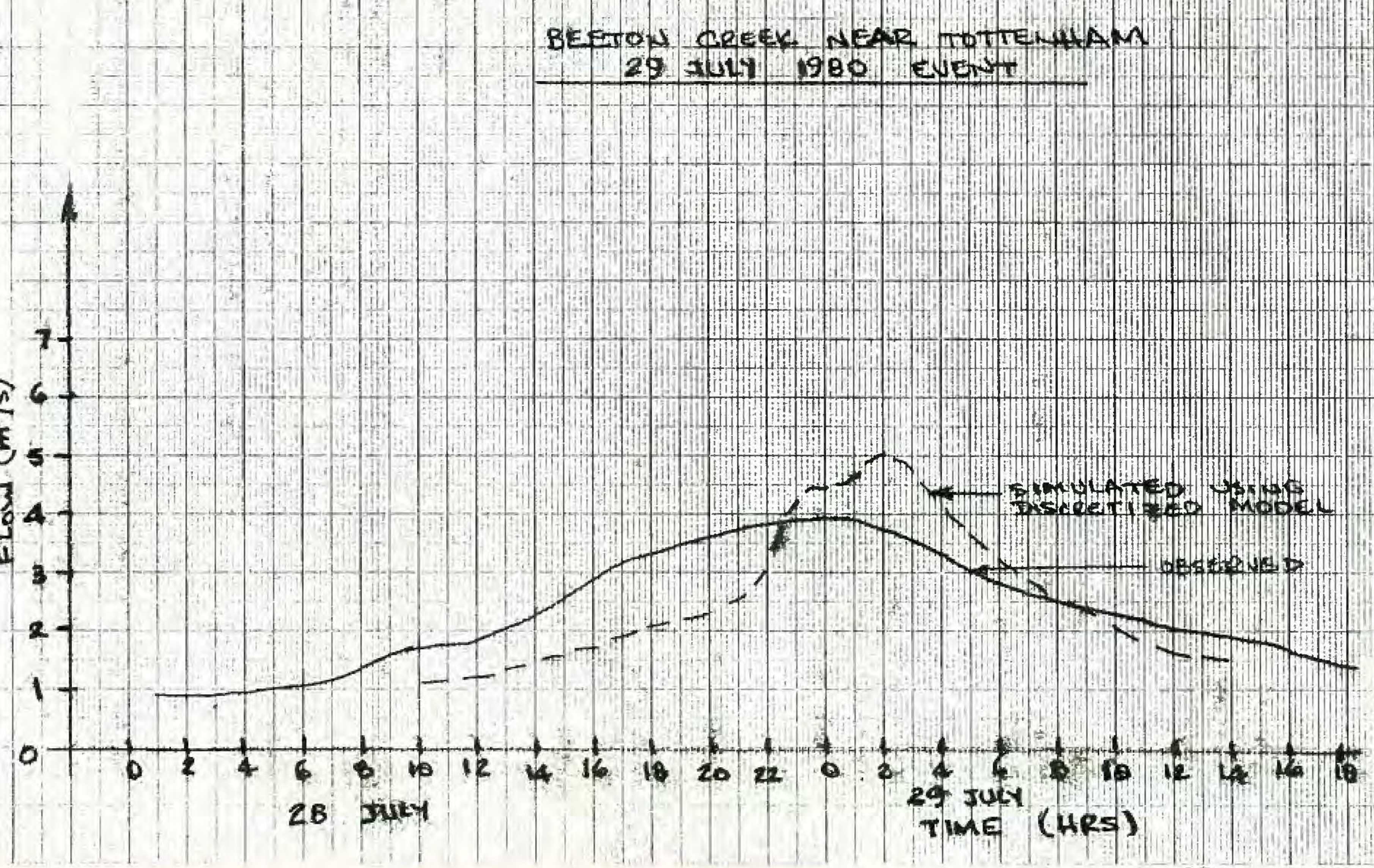

BEETON CREEK NEAR TOTTENHAM
29 JULY 1980 EVENT
Flow (m³/s)
0
1
2
3
4
5
6
7
0 2 4 6 8 10 12 14 16 18 20 22 0 2 4 6 8 10 12 14 16 18
28 JULY
29 JULY
TIME (HRS)
SIMULATED USING DISCRETIZED MODEL
OBSERVED

Fig. 3.4 (e)

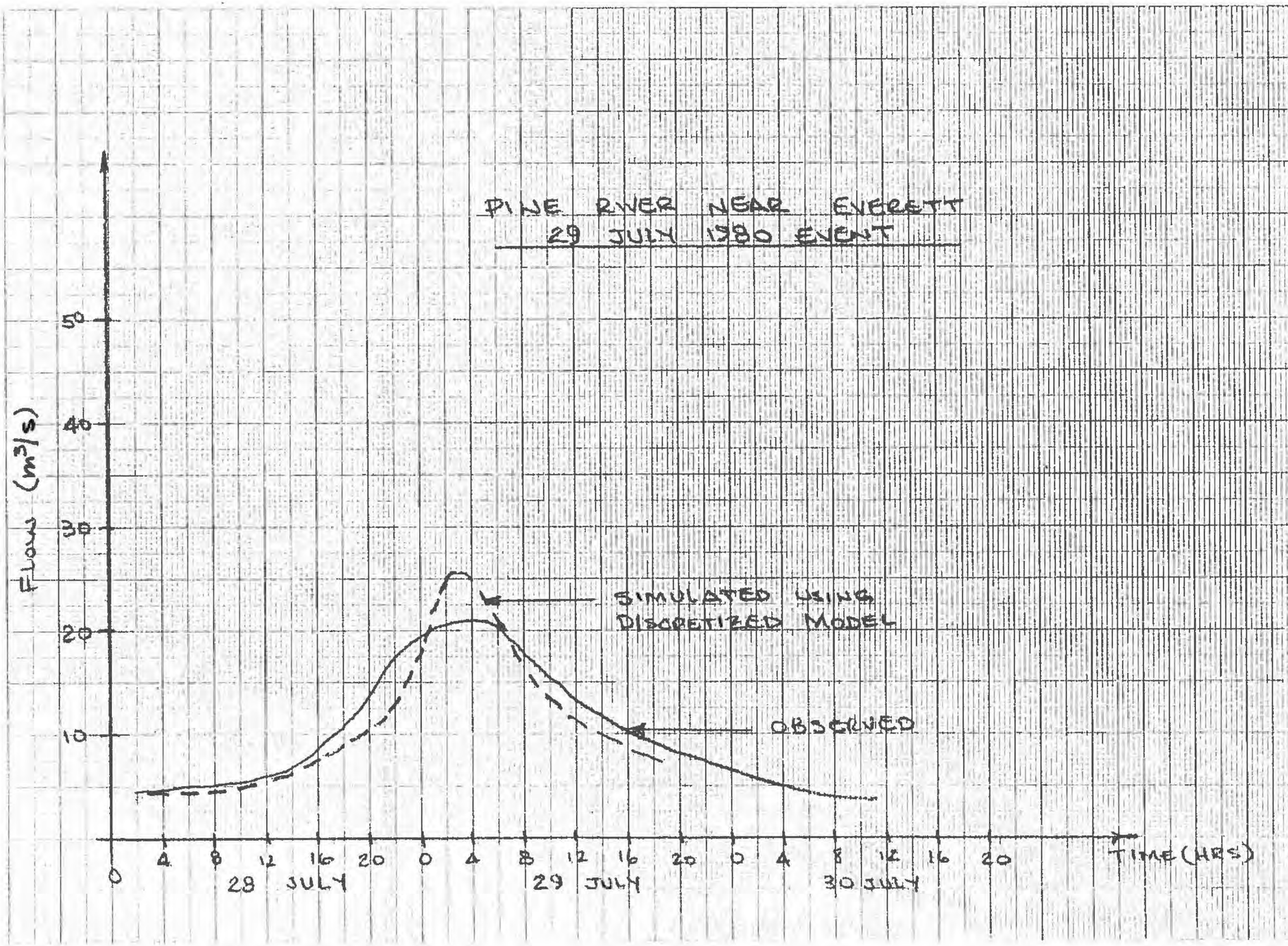

PINE RIVER NEAR EVERETT
29 JULY 1980 EVENT
SIMULATED USING DISCRETIZED MODEL
OBSERVED
FLOW (m³/s)
50
40
30
20
10
0
4
8
12
16
20
28 JULY
29 JULY
30 JULY
TIME (HRS)

Fig. 3.4 (f)

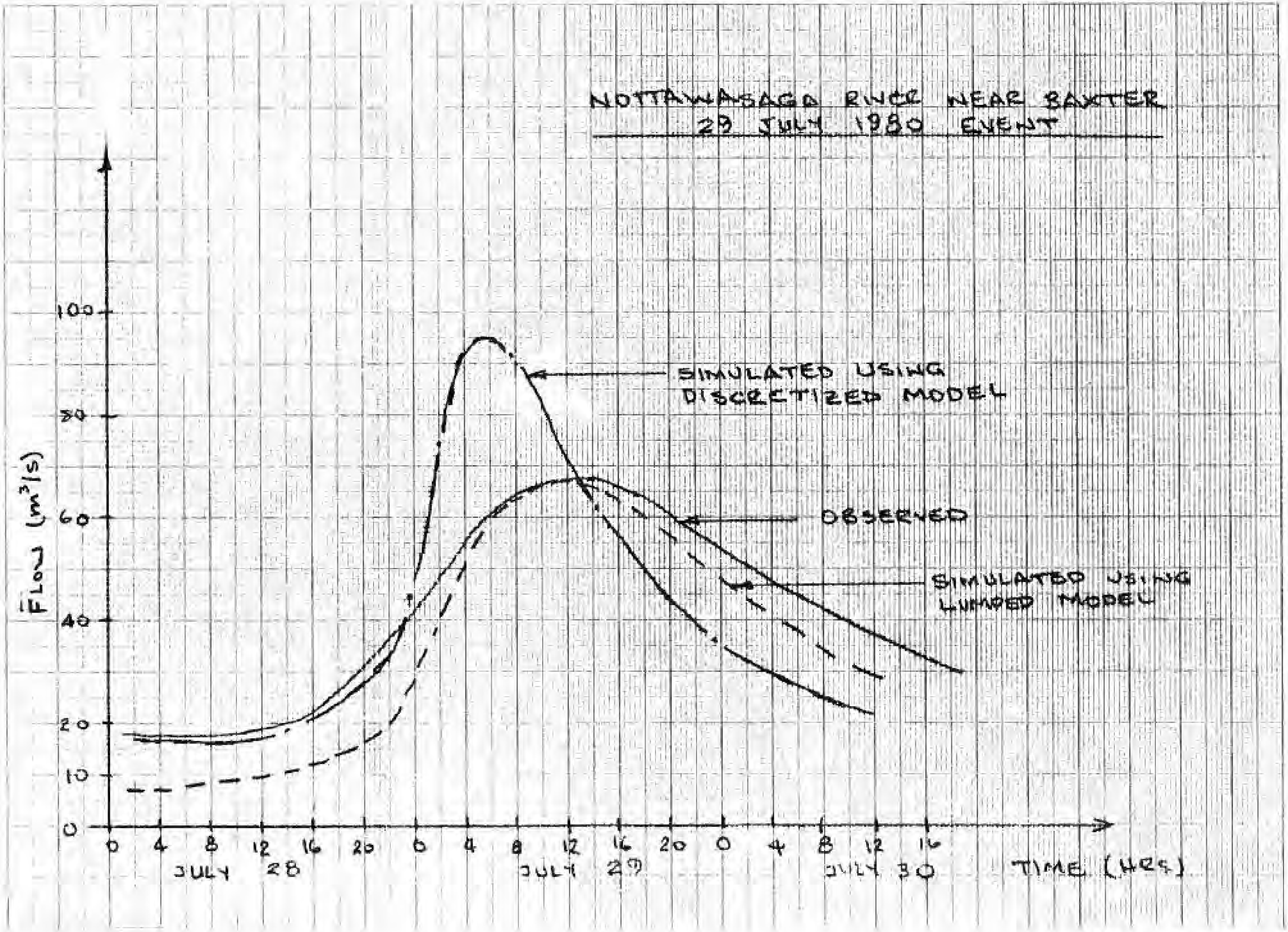

NOTTAWASAGA RIVER NEAR BAXTER
29 JULY 1980 EVENT
SIMULATED USING DISCRETIZED MODEL
OBSERVED
SIMULATED USING LUMPED MODEL
FLOW (m³/s)
100
80
60
40
20
10
0
0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16
JULY 28
JULY 29
JULY 30
TIME (HRS)

Fig. 3.4 (g)

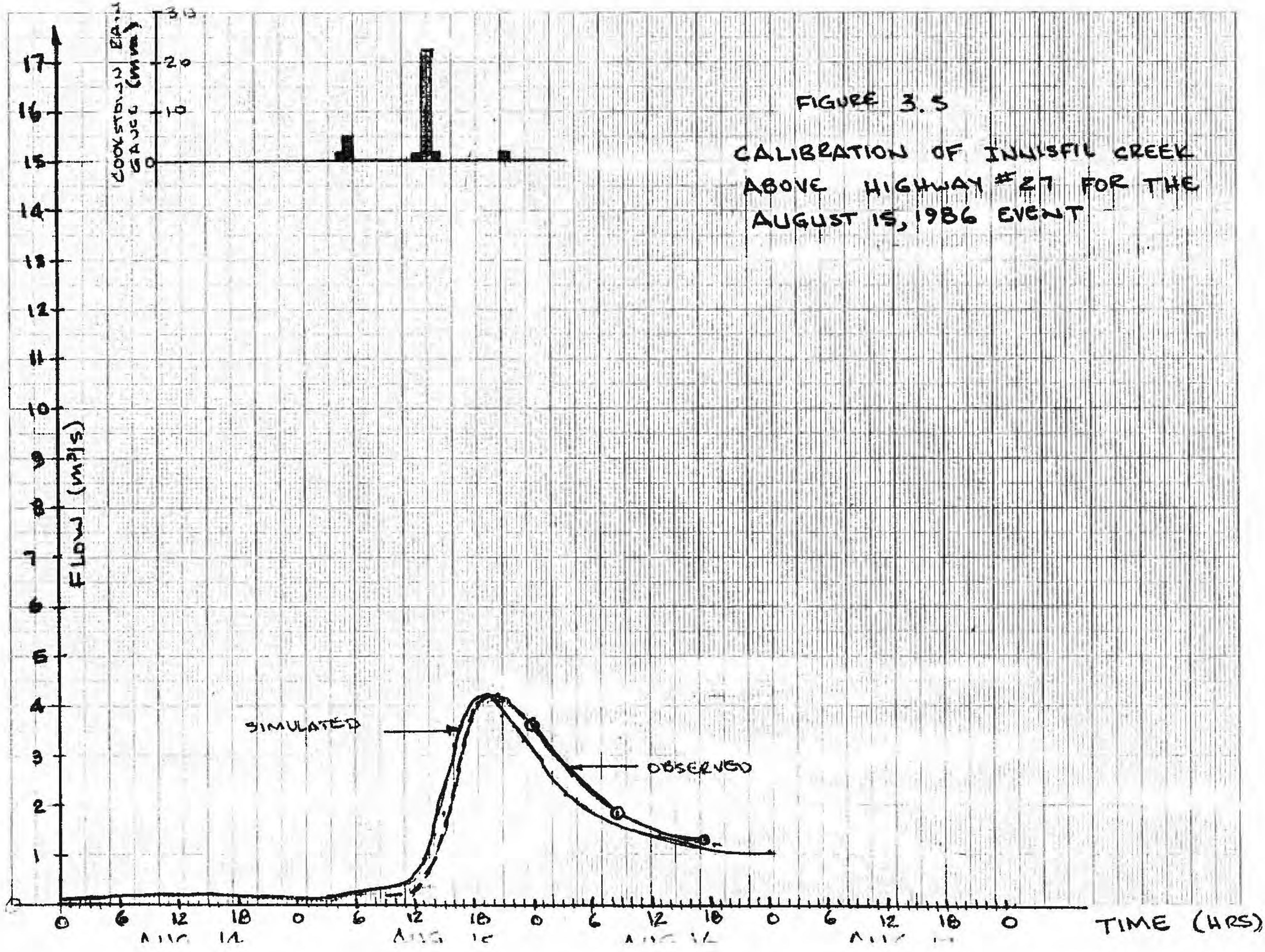


FIGURE 3.5

CALIBRATION OF INNISFIL CREEK ABOVE HIGHWAY #27 FOR THE AUGUST 15, 1986 EVENT

3.2.4.2.3 Calibration of Spring Events

The computer plots of daily streamflow for the 1975-1984 period were similarly screened to identify suitable calibration and validation events for the spring period. As indicated previously, suitable calibration events were selected from the 1980-1984 period and validation events from the 1975-1979 period. The calibration events selected are shown in Table 3.8. Some high flow events could not be selected because hourly streamflow data from November to early March was not available. The Boyne River gauge at Earl Rowe Park has missing hourly flow data for several events in late March and April.

The observed rainfall and snow course water equivalent data is also presented in Tables 3.8. The snow water equivalent is highly variable for the various snow courses; therefore, for modelling purposes it was not possible to accurately initialize snowpack water equivalent. To circumvent this problem, the modelling was started on November 1 and run through the winter period to about the end of April. In this manner the snowmelt model parameters could be more accurately calibrated.

In the calibration exercise, lack of actual hourly precipitation data provided serious problems. Although the AES provides hourly precipitation data for the winter period, the precipitation data usually consists of 24 equal values per day since the AES does not operate the recording precipitation gauges during the winter period. In some cases a thaw occurred accompanied by rainfall but actual rainfall distribution was not available. Where this occurred, the 24 equal values provided by the AES were redistributed using the 6-hour totals from the Mount Forest station. However, this also created some difficulty because of the distance of the Mount Forest station from the NVCA and the actual rainfall distribution within the 6-hour period was not known.

TABLE 3.8

SPRING CALIBRATION EVENTS

WATERCOURSE	PEAK FLOW (m³/s) Date	Observed (m³/sec)	Simulated	Type of Event	OBSERVED RAINFALL (mm) Date	Barrie	Shanty Bay	Allis-ton	Shel-burne	Redick-ville	OBSERVED SNOW WATER EQUIVALENT (mm) Date	Eden-vale	Colwell	Totten-ham	Mono Centre	Maple Valley	SIMULATED Snow Water Equivalent (mm)
Mad River at Glencairn	21 Mar. 1980	74.4	75	Rainfall	20 Mar. 21 Mar.	16.8 14.4	19.2 21.6	18 13.6	14.4 16.8	0 45.6	01 Mar. 15 Mar. 01 Apr.	20 40 0	18 30 0	- - 0	35 46 0	35 - -	43.2 54 0
	31 Mar. 1982	90	102	Rainfall on Snowmelt	30 Mar. 31 Mar.	14.4 0	11.4 TR	13.0 0	24.0 0	0 26.4	15 Mar. 01 Apr. 15 Apr.	147 0 0	91 0 0	46 0 0	122 61 0	163 112 0	162 69 30
	04 Apr. 1984	37	37	Rainfall on Snowmelt	04 Apr. 05 Apr.	13.8 4.6	14.0 7.3	- -	9.6 3.0	0 24.9	15 Mar. 01 Apr.	46 0	43 0	20 0	33 0	71 0	53 24
Willow Creek above Little Lake	21 Mar. 1980	35.3	33.5	Rainfall	20 Mar. 21 Mar.	16.8 14.4	19.2 21.6	18 13.6	14.4 16.8	0 45.6	01 Mar. 15 Mar. 01 Apr.	20 40 0	18 30 0	- - 0	35 46 0	35 - -	102 112 13.6
	31 Mar. 1982	20	27.5	Rainfall on Snowmelt	30 Mar. 31 Mar.	14.4 0	11.4 TR	13.0 0	24.0 0	0 26.4	15 Mar. 01 Mar. 15 Apr.	147 0 0	91 0 0	46 0 0	122 61 0	163 112 0	210 110 43
Boyne River at Earl Rowe Park	05 Apr. 1984	17.5	19.5	Rainfall on Snowmelt	04 Apr. 05 Apr.	13.8 4.6	14.0 7.3	- -	9.6 3.0	0 24.9	15 Mar. 01 Apr.	46 0	43 0	20 0	33 0	71 0	36.8 12.1