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ELBOW RIVER FLOOD REPORT

A Study of Potential Flooding Problems

Along the Elbow River in Calgary.

Prepared by:

Alberta Department of Water Resources,

F.L. Grindley, Director.

Sept 28, 1965

ELBOW RIVER FLOOD REPORT

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ELBOW RIVER FLOOD REPORT

List of Illustrations

ACKNOWLEDGEMENTS

The Department of Water Resources is indebted to several agencies for the material contained in this report. Detailed flood crest information - photographs, profiles and discharges (Appendix B, C and D) all came from the Calgary offices of the Federal Water Resources Branch. Newspaper reports of past floods were studied in the offices of the Calgary Herald, Calgary Albertan and Glenbow Foundation.

INTRODUCTION

The City of Calgary has suffered flood damage periodically ever since the establishment of a settlement at the junction of the Elbow and Bow Rivers, at least ever since records were first kept. Old newspapers contain detailed descriptions of the floods of 1915, 1923, 1929 and 1932, refer briefly to floods in 1902, 1897 and 1884 and mention (in 1897) that Calgary's greatest flood occurred in 1879. Often the total flood damage resulted from a coincidence of high water on both of the two rivers but it is possible to separate their effects and consider the threat posed by each. This present study is concerned with the Elbow River.

In 1932 the Glenmore Dam was constructed across the Elbow on the south-western outskirts of Calgary to provide a reservoir for the city water supply. By a fortunate coincidence the reservoir was still empty when the greatest recorded flood on the Elbow River (25,000 c.f.s.) swept down in 1932. The Glenmore reservoir storage cut the peak flow to 11,300 c.f.s., preventing extensive damage, although even at this tempered stage flooding was severe. Development of the flood plain of the Elbow River valley is undoubtedly much greater today than it was in 1932.

Since 1932 there have been no major floods on the Elbow. This has been popularly credited to the presence of the Glenmore Dam in all likelihood, but, in fact, this assumption breeds false security because :

(a) by some hydrological freak phenomena, there have been no major floods anywhere on the Elbow since 1932, (b) the Glenmore reservoir does not have enough live storage to significantly dampen a large flood. A high reservoir level is maintained in order that sufficient head is available to power the hydro generators supplying electricity to the pumping system.

A further cause for anxiety is the narrowing of the Elbow River channel that has taken place over the years. A number of landowners whose property abuts the river have taken advantage of long periods of relatively low flow to encroach into the river channel. The net effect, of course, is a decrease in channel capacity.

In 1962 the Hydrology Division of the Department of Water Resources, in response to a request to the Department of Water Resources from the City of Calgary City Engineer, began a study of the potential flooding danger along the Elbow River in an attempt to delineate the areas which would likely be under water for various probabilities of flood occurrence.

PRELIMINARY WORK

The City of Calgary arranged, early in 1962, for the production of a 2-foot contour map of the Elbow River valley. This map has provided the basic topographical data for almost the whole study. In addition, special surveys to determine channel cross-sections in several constricted areas were done by the City of Calgary Engineering Department.

FREQUENCY STUDIES

Natural river flows were used in calculating flood frequency through Calgary. Present plant operation at Glenmore Dam results in the maintenance of a very high reservoir level, nullifying any potential flood dampening possibilities.

A regular hydrometric station was maintained on the Elbow River at Calgary in the vicinity of the Exhibition Grounds during the period 1908 - 1932. Since that time estimates of flow into, and out of, the Glenmore reservoir have been made by the City of Calgary Waterworks Department. Because these later records seem strangely unlike the former and because the discharges are not actually measured, the 1933-1964 record has not been accepted as valid in conducting frequency studies. In this connection it should be noted that a new hydrometric station located just upstream from Glenmore reservoir will begin operation shortly. If the City of Calgary is concerned about the measurement of downstream flow a request should be made to the proper authorities for the installation of a standard hydrometric station below the dam.

There are several methods for plotting frequency curves from short records:

(a) use only the years of record available (Figures 1a & 1b),

(b) estimate missing records from correlation curves (Figures 2 & 3) and use these values in plotting frequency curves for the total period (Figures 4a & 4b),

(c) estimate missing data from records taken at a close-lying hydrometric station and add these to the original records to plot a frequency curve covering the complete period (Figures 5a & 5b).

In this case, the floods at Calgary during the period 1935-1964 were assumed to be equal to flood magnitudes of the Elbow River at Bragg Creek multiplied by a factor of 1.2. The factor may seem low considering the great difference in drainage areas (471 square miles compared to 300 square miles), but the following considerations prompted its use:

1. The estimated flood flows at Calgary for the period 1935-1964 are much lower than the 1.2 multiplicand factor would indicate.

2. The odd shape of the Elbow River basin brings all the mountain and foothills runoff in above the Bragg Creek station while the basin area between Bragg Creek and Calgary is much flatter and considerably less well drained.

3. Correlation plots of floods at Bragg Creek and at Calgary vs. floods on the Highwood at Alderysde produce fitting lines that differ by about 20% (Figure 3).

Both log-probability and Gumbel paper were used in plotting the frequency curves for comparison purposes.

It may be noted that during several years two or three flood peaks occurred. However, only in 1923 did any of the secondary floods exceed the 20% probability level. They are therefore of minor importance and the use of the annual maximum is justified.

The Federal Water Resources Branch estimate that the peak instantaneous flow in 1932 was 25,000 c.f.s. From their estimated inflow hydrograph, we have calculated the maximum 24 hour average for this flood to have been about 15,700 c.f.s. In like fashion, the maximum 24 hour averages for 1915, 1923, and 1929, peaks were plotted rather than the published daily flow figures.

The following table details the various flood frequencies accepted for this study:

Frequency	Peak Annual Flood	
	Average Daily c.f.s.	Instantaneous c.f.s.
20%	4,500	
10%	7,400	10,000
5%	11,000	15,000
2%	17,000	23,000
1%	23,000	32,000

It should be noted that when this study was first begun values for the instantaneous peak floods for 5%, 2%, and 1% probabilities were thought to be 15,500 c.f.s.; 25,000 c.f.s., and 34,000 c.f.s. so that profile calculations were done for those floods. The difference in calculated flood levels between these discharge values and those now accepted would be very slight.

FLOOD LEVEL CALCULATIONS

Records of flood peaks from the old gauging station located a few hundred feet downstream from the 12th Avenue S.E. Bridge (station 2300) and cross-sections taken from the 2' contour map provided the basic information for estimates of possible flood levels. Three sets of flood

levels, one obtained during the 1915 flood, one in 1923 and the other measured during the test flow of 5000 c.f.s. in June, 1964, proved to be extremely valuable additions to the gauge record.

Water surface profiles corresponding to various flood frequencies were calculated by the use of the standard step method for computing backwater curves. This method is covered fully in Chapter 9 of the book "Flow in Open Channel" by Woodward and Posey as well as in other books. Briefly, it consists of the use of Manning's formula for open channel flow coupled with a trial-and-error computation to calculate stream profiles. A description of the various problems and assumptions involved follows:

Base level, coincidence of floods on the Bow and Elbow

A study of the hydrometric records for 1915, 1923, 1929, and 1932 revealed that major floods on the two rivers often occur in the same day. In 1915, 1923, and 1929, the difference between the peak gauge and low water on the Elbow amounted to 1 to 2 feet more than the comparable rise on the Bow. The additional control on the Bow River headwaters that has come into being since 1932 is a further factor to consider in estimating the probable base level for the Elbow River during a future flood. These considerations prompted the use of the base levels at the mouth of the Elbow shown in Figure 9. The question is important only insofar as the first thousand foot reach upstream from the mouth is concerned, because the constricted channel between stations 410 and 1500 superimposes its own control above that.

Calculation of Manning's "n"

Several reasonable values of "n" were used to calculate the water surface elevation at the gauging station site for a flow of $5,500 c.f.s. and these computed levels were compared to a level taken from the gauge height vs. flood discharge curve (Figure 8). The value of 0.035 explained flood levels at station 2300 (gauging station). This value was then used to calculate the profile for 5000 c.f.s. which was then compared to that measured during the test flow in 1964. Close agreement (i.e. a variation of $\frac{1}{2}'$ or less) between calculated and measured values confirmed the value of 0.035 from stations 0+00 to 153+40. In order to reproduce the measured profile it was necessary to use an "n" value of 0.055 from stations 158+50 to 163+30 and at 189+50, both areas where the river splits and flows around islands, and to use 0.05 between stations 246+50 and 257+50. A possible explanation for a higher roughness value in this latter stretch is the presence of a few more boulders than usual and the movement through this reach, at present, of a gravel bed load not evident elsewhere when the site was visited.

These same "n" values were then used to calculate profiles for the higher flows with the following exceptions:

1. In calculating flow over the flood plain from stations 103+80 to 118+00, an "n" value of 0.05 was used.
2. It was assumed that velocity would not exceed the critical value so that when the step computations indicated super-critical flow, critical velocity only was assumed to occur. The reasoning here was that the banks would have eroded during the floods of 1915, 1923, and 1932,

broadening the channel considerably if supercritical flows had actually occurred and, therefore, the channel roughness must be great enough in these sections to cut the flow velocity at least to the critical stage. As a matter of interest, the computations showed critical velocity for a flow of 15,500 c.f.s. in the vicinity of stations 95+70 to 98+60 and 110+60 to 113+30.

Hydraulic components, cross-sectional area, wetted perimeter

Except for those reaches in which special surveys were carried out, channel cross-sections were obtained directly from the 2-foot contour maps. In areas where trees and brush grow thickly on the bank, obviously offering considerable resistance to flow, the cross-sectional areas determined from ground contours were decreased accordingly. This condition exists to a lesser or greater degree along about half the length of the channel for the higher flows.

The actual amount of water spilling out of the channel and flowing down streets, across yards, etc. was impossible to intelligently estimate, but since it was considered to be an insignificant proportion of the total flood flow, the total flow was assumed to be carried along the main course of the river channel, bounded either by vegetation or by the closest buildings.

Wetted perimeter was assumed to be equal to the water surface width between the above mentioned obstructions.

Area of flow beneath the water surface shown on the 2-foot contour map was estimated for each section by a rough application of Manning's formula using an "n" value of 0.1, in conjunction with low flow records from the old hydrometric stations, and slopes taken from the 2-foot contour map. The special cross-sectional surveys that were run gave results generally in agreement with these roughly calculated values and, in any case, the possible errors would be insignificant in calculation of flood profiles, especially for floods of the order of 10,000 c.f.s. or greater.

No extra head loss was allowed for flow through bridge openings.

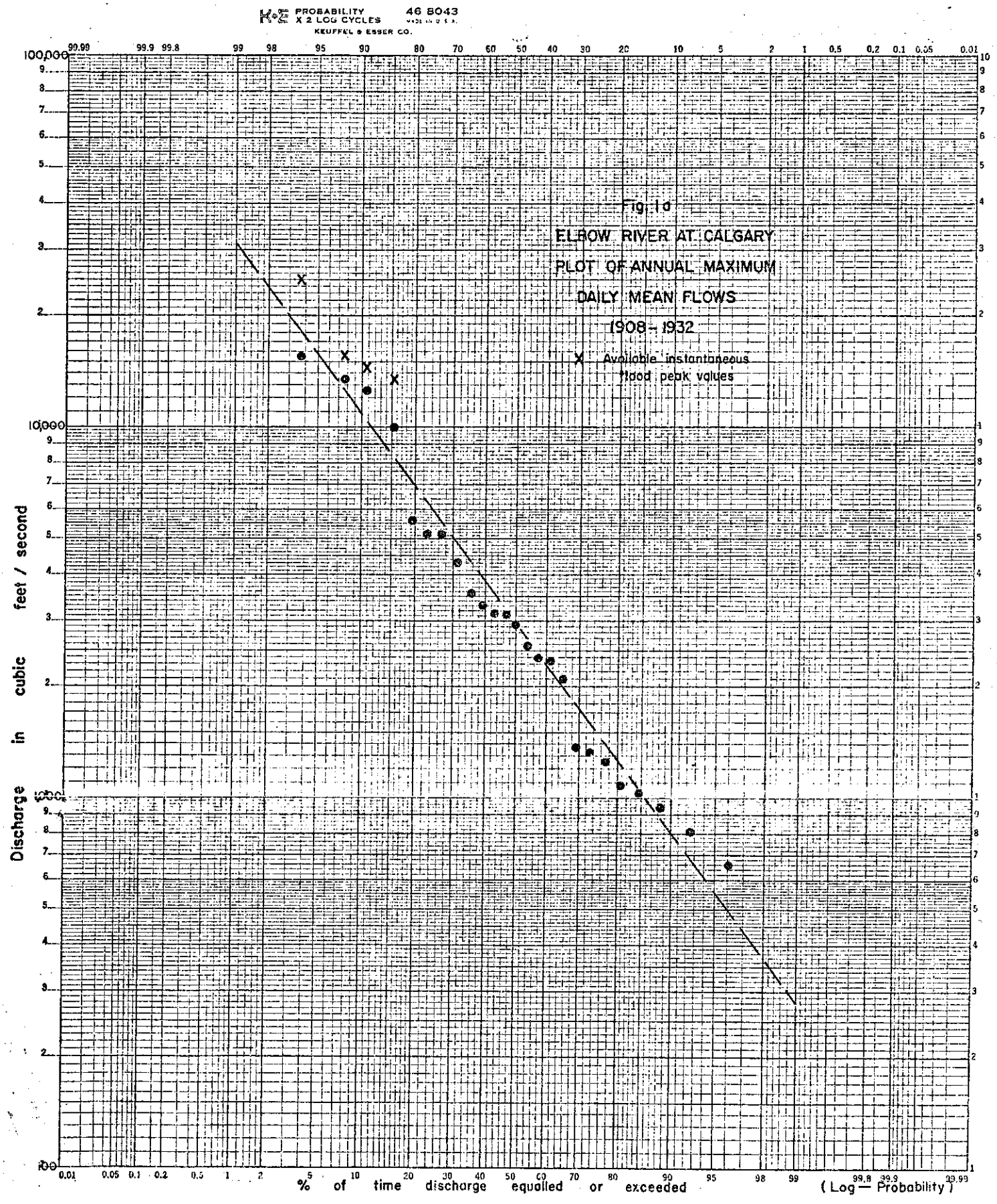
Backwater calculations were not carried upstream past station 306+50 because the February 1962 profile taken from the contour map begins a sharp upward trend at this point and crosses the 5000 c.f.s. profile at station 350+00. Either there is an error in the map or profile, or there was a huge build-up of ice at the time the aerial photos for the map were taken.

SUMMARY AND CONCLUSIONS.

Calculated flood profiles and the areas which would likely be covered by flood waters of various frequencies are shown on Figures 6, 9, and 10. A start was made on a 34,000 c.f.s. profile but so much overflow would take place that the assumptions used in these backwater calculations probably break down. In cases where the 25,000 c.f.s. flow fills the whole valley, that is,upstream from the 4th Street S.W. bridge, there would be little additional area covered by an extra 9,000 c.f.s., although the depth of water would be greater. Downstream from this, however, a 34,000 c.f.s. flood would cover a considerably larger area to the north.

This whole study has been based on the assumption of natural flood flows occuring on the Elbow River. If the City of Calgary should decide to maintain Glenmore reservoir at a lower level than has been the practice in the past, a measure of flood protection could be attained. It is well, however, to note that the absolute maximum control available was used in 1932 when a flood of 25,000 c.f.s. filled the hitherto empty reservoir and still produced a flood peak of 11,300 c.f.s. downstream.

September 28, 1965,
R.K. Deeprose, P. Eng.,
Hydrology Division,
Department of Water Resources,
Government of Alberta.


K+E PROBABILITY 46 8043
X 2 LOG CYCLES
KEUFFEL & ESSER CO.
Fig. 1d
ELBOW RIVER AT CALGARY
PLOT OF ANNUAL MAXIMUM
DAILY MEAN FLOWS
1908 - 1932
X Available instantaneous flood peak values
Discharge in cubic feet / second
% of time discharge equalled or exceeded
(Log — Probability)

R.E.O.R. 5B-10-28

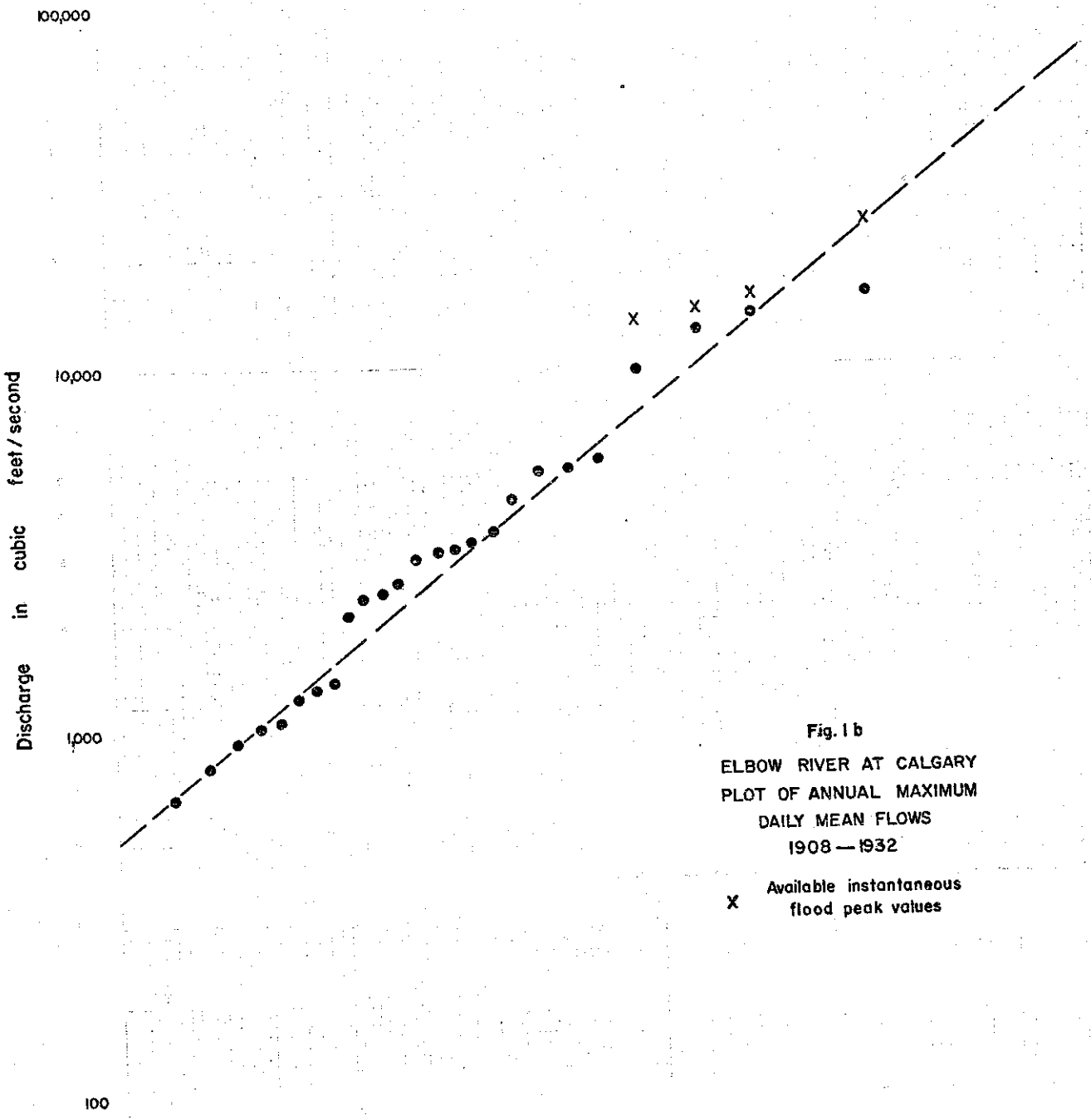


Fig. 1 b

ELBOW RIVER AT CALGARY

PLOT OF ANNUAL MAXIMUM DAILY MEAN FLOWS

1908 — 1932

X Available instantaneous flood peak values

K+E LOGARITHMIC 46 7320
2 X 3 CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.

R.E.D.R. 5B-10-38

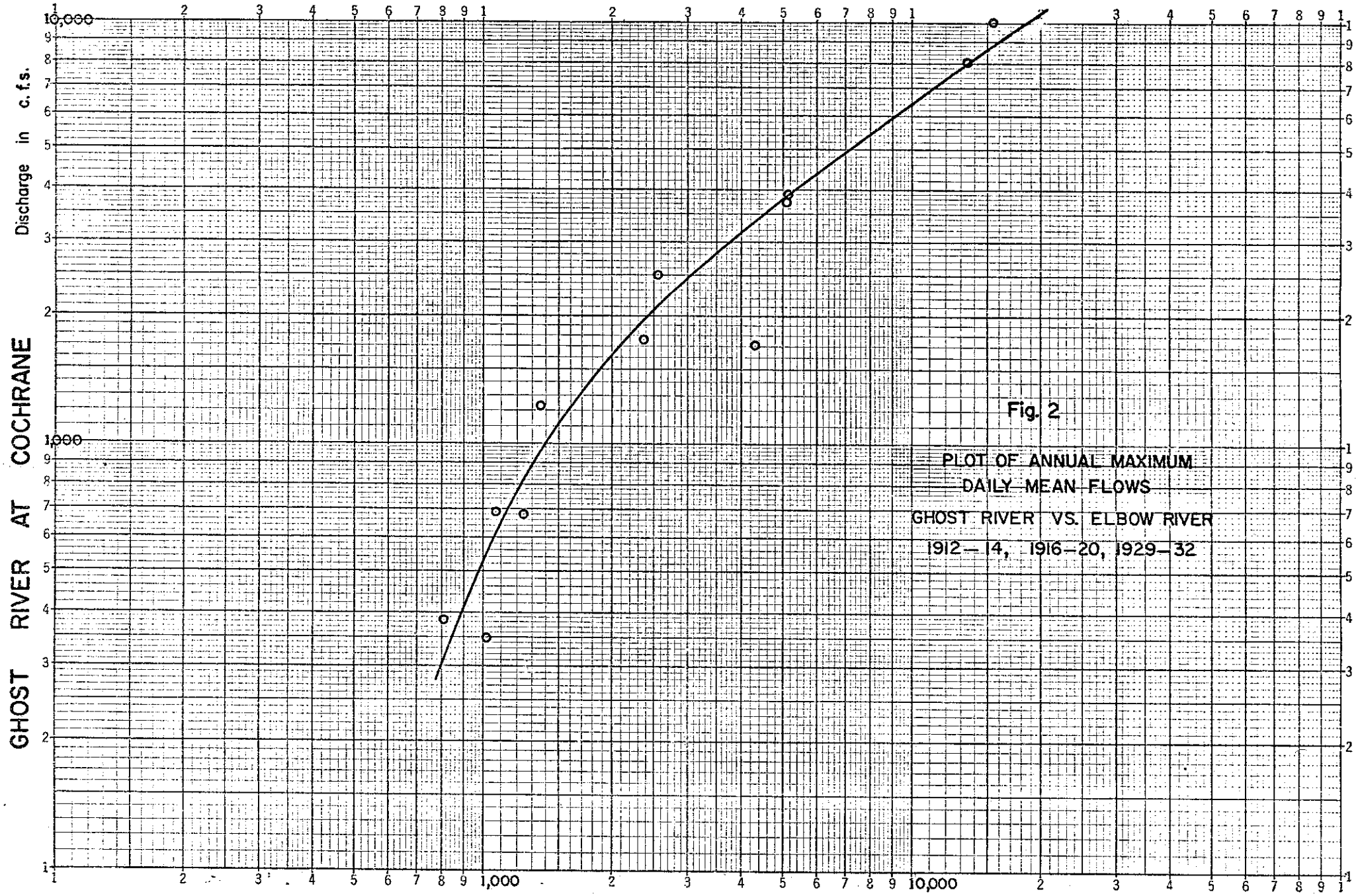


Fig. 2

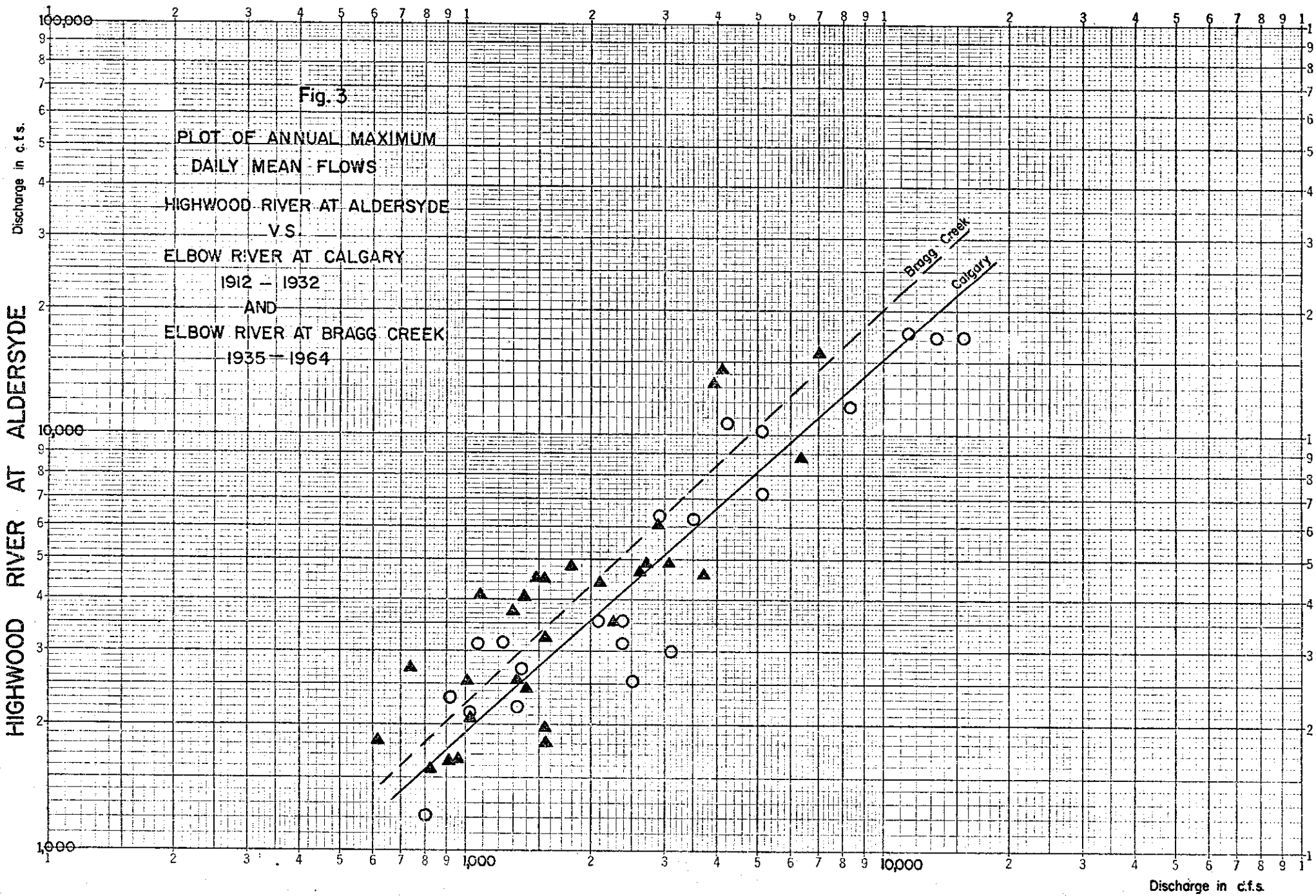
PLOT OF ANNUAL MAXIMUM DAILY MEAN FLOWS

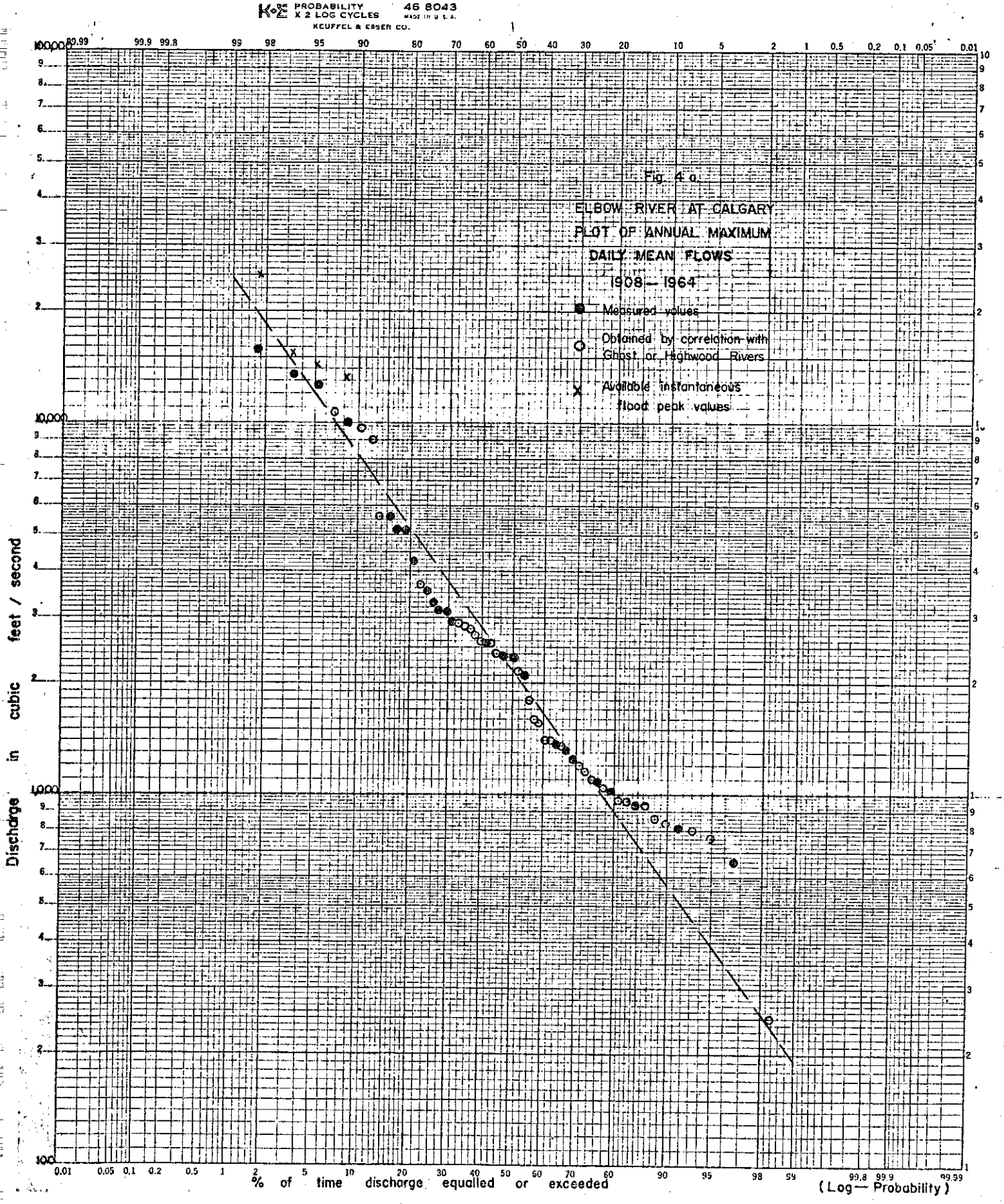
GHOST RIVER VS. ELBOW RIVER

1912–14, 1916–20, 1929–32

K+E LOGARITHMIC 46 7320
2 X 3 CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.

Re.0.2.5B-10-4B




K+E PROBABILITY 46 8043
X 2 LOG CYCLES MADE IN U.S.A.
KEUFFEL & ESSER CO.
Fig. 4 a.
ELBOW RIVER AT CALGARY
PLOT OF ANNUAL MAXIMUM
DAILY MEAN FLOWS
1908 — 1964
Measured values
Obtained by correlation with Ghost or Highwood Rivers
Available instantaneous flood peak values
Discharge in cubic feet / second
% of time discharge equalled or exceeded
(Log — Probability)

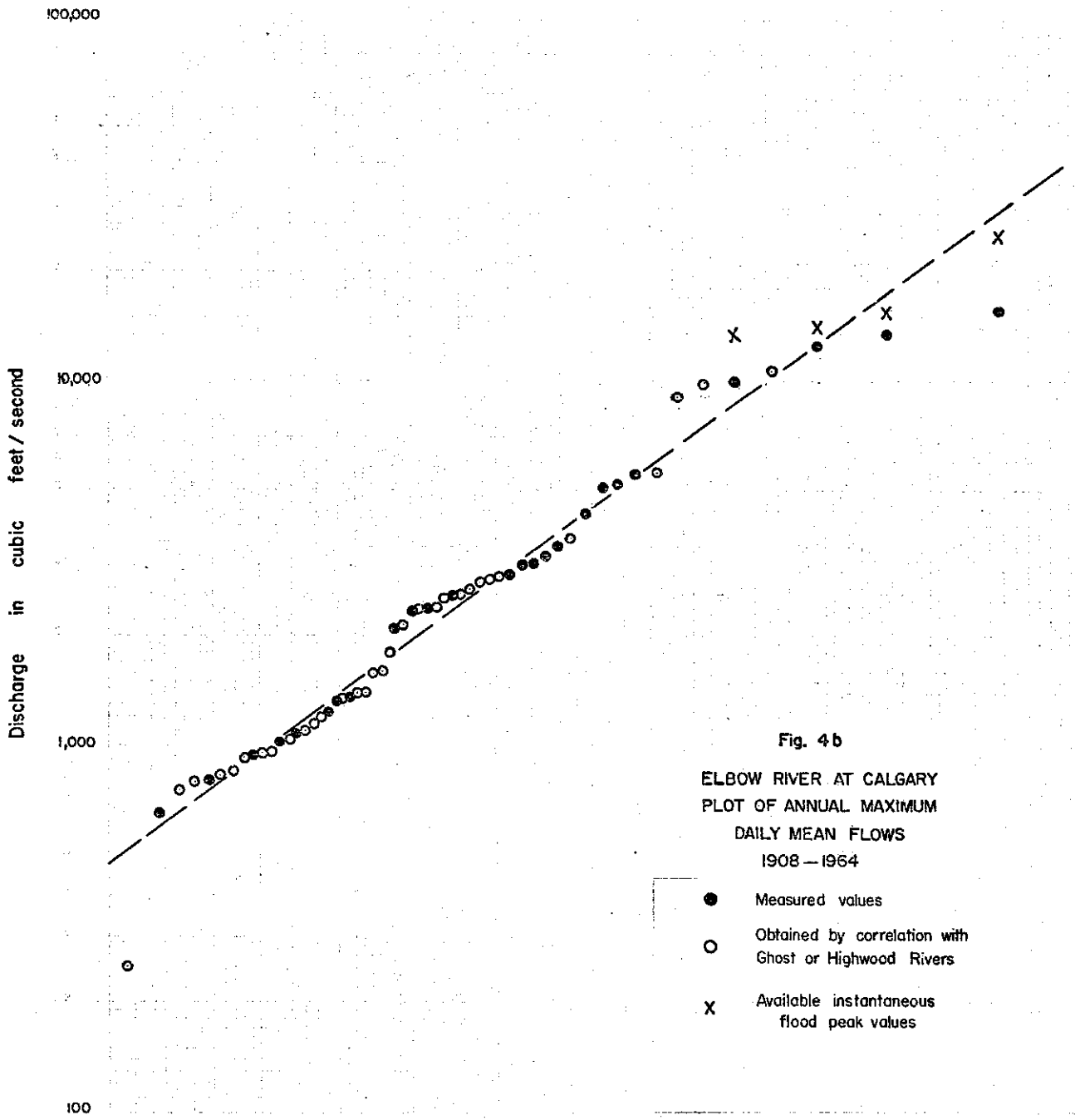


Fig. 4b

ELBOW RIVER AT CALGARY
PLOT OF ANNUAL MAXIMUM
DAILY MEAN FLOWS
1908 — 1964

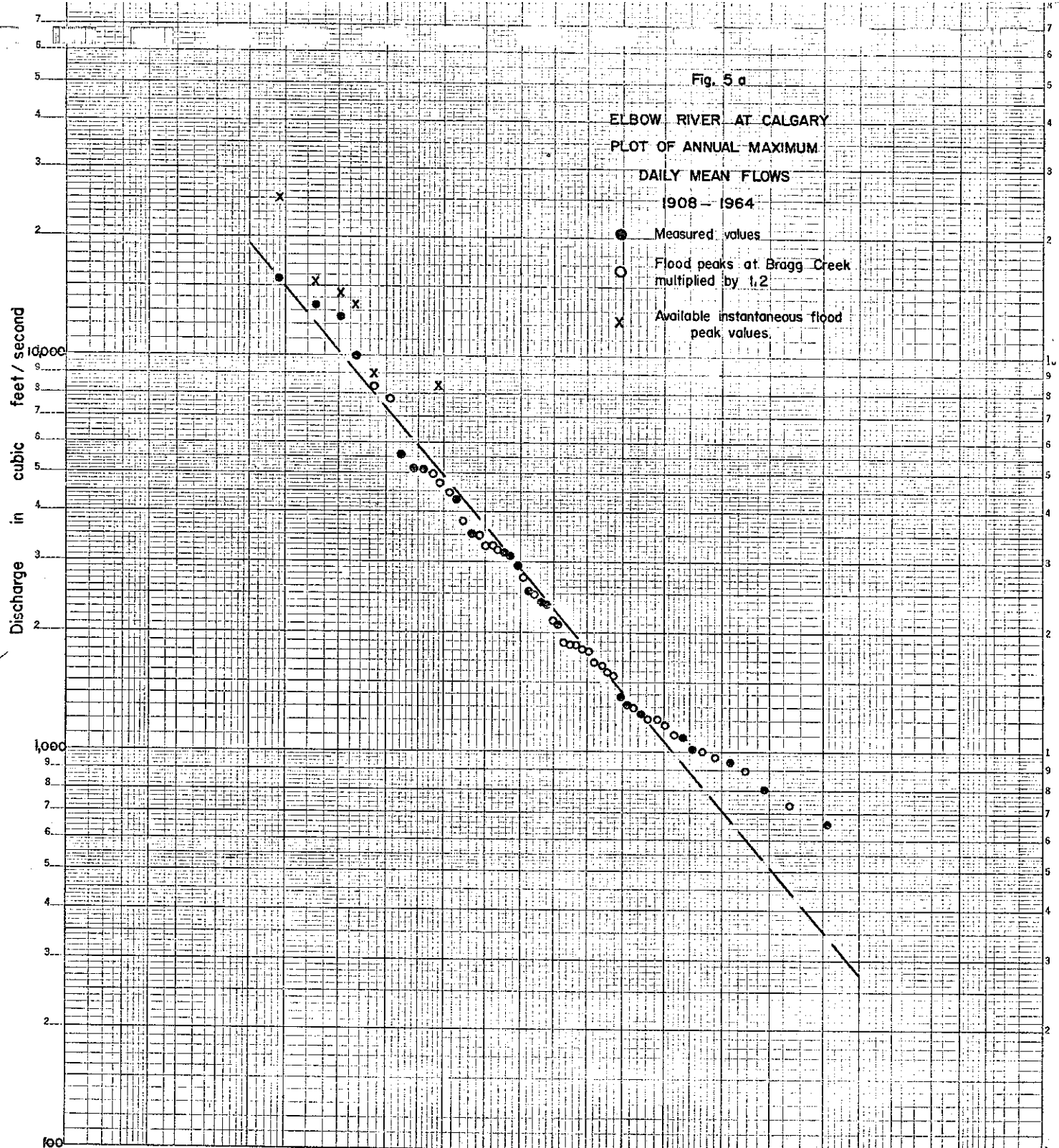


Fig. 5 a
ELBOW RIVER AT CALGARY
PLOT OF ANNUAL MAXIMUM
DAILY MEAN FLOWS
1908 – 1964
Measured values
Flood peaks at Bragg Creek multiplied by 1.2
Available instantaneous flood peak values.
Discharge in cubic feet / second
10,000
1,000
100
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20

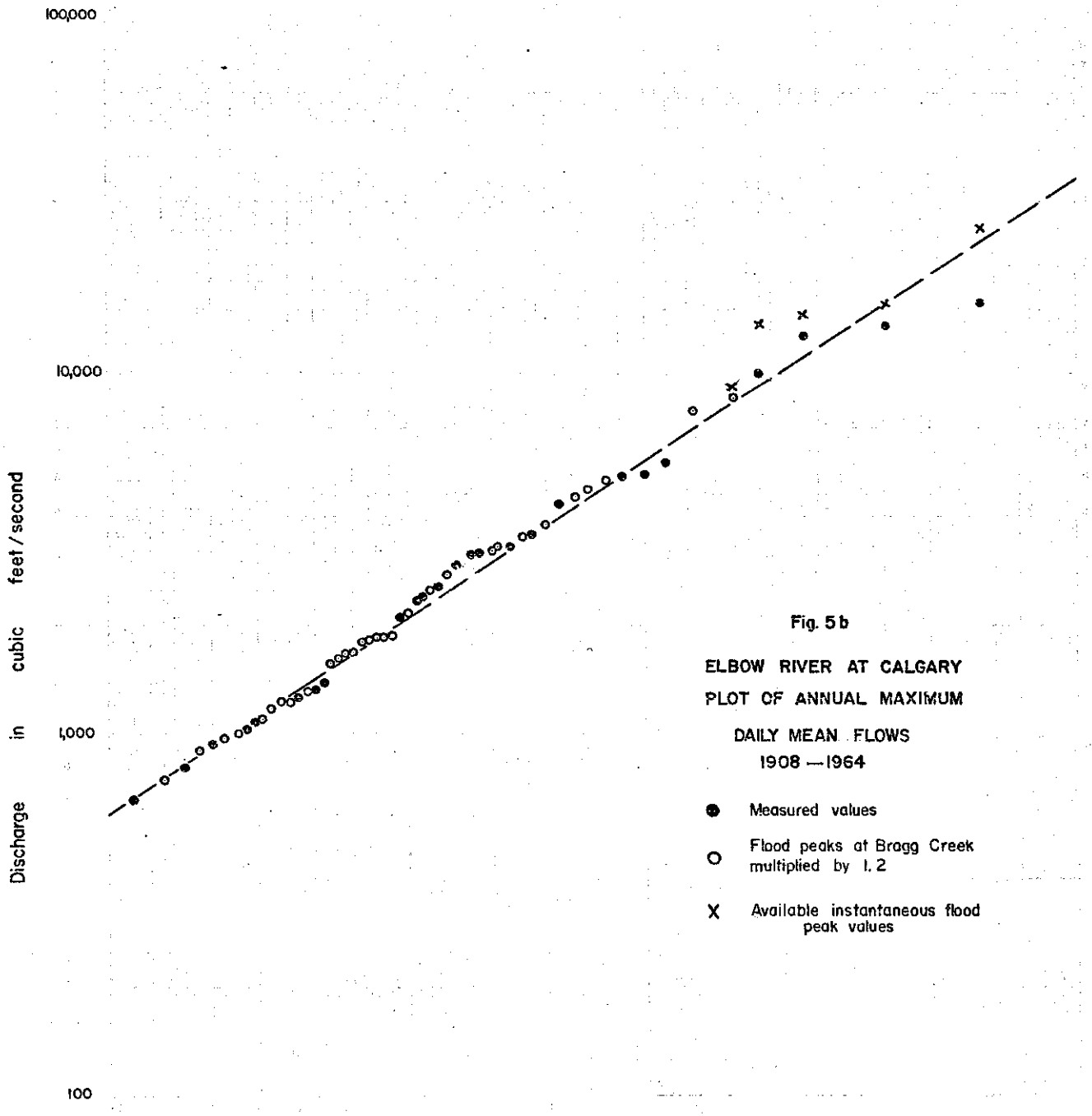


Fig. 5b

ELBOW RIVER AT CALGARY

PLOT OF ANNUAL MAXIMUM

DAILY MEAN FLOWS

1908 — 1964

● Measured values

O Flood peaks at Bragg Creek multiplied by 1.2

X Available instantaneous flood peak values

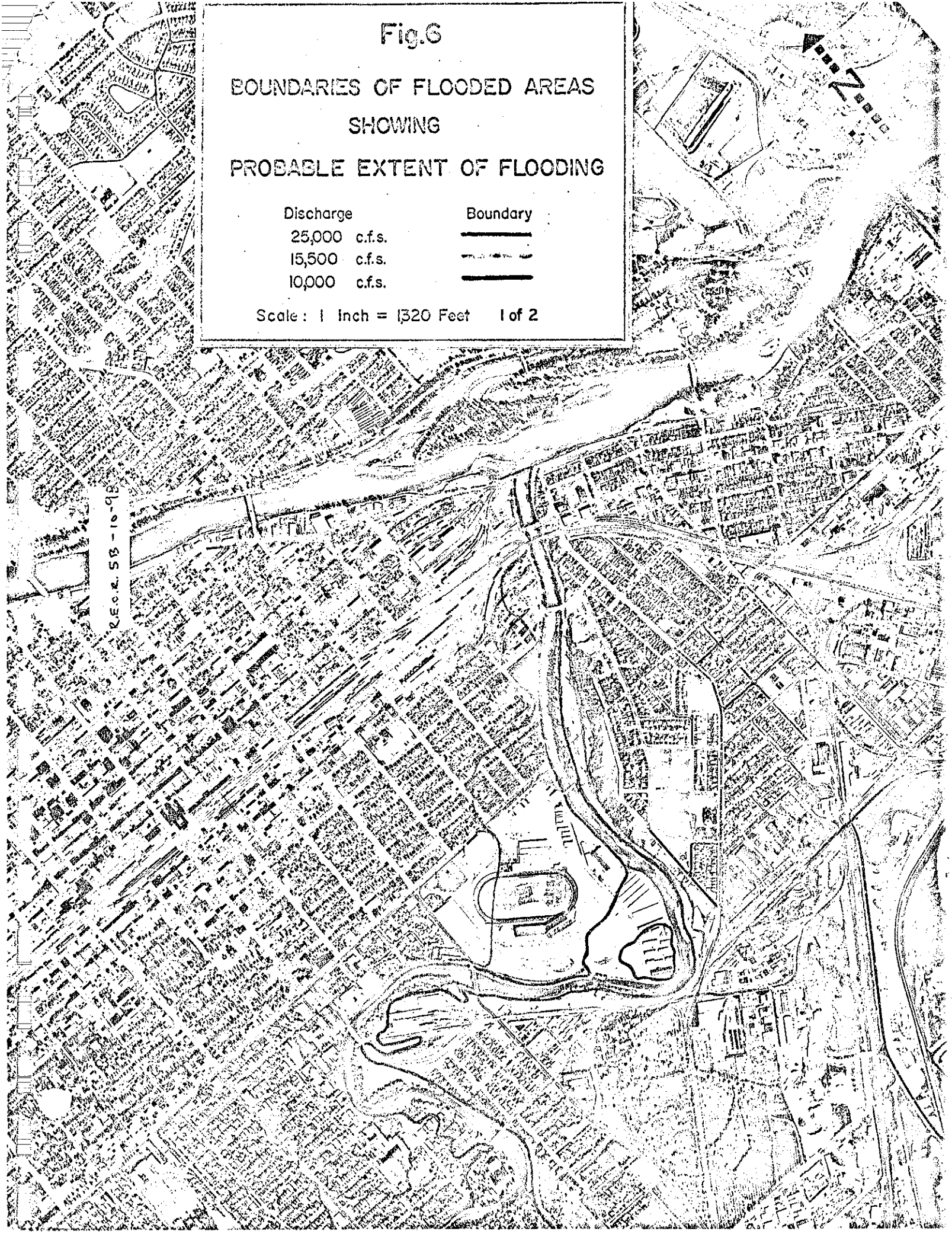


Fig.6
BOUNDARIES OF FLOODED AREAS
SHOWING
PROBABLE EXTENT OF FLOODING
Discharge
Boundary
25,000 c.f.s.
15,500 c.f.s.
10,000 c.f.s.
Scale : 1 Inch = 1320 Feet
1 of 2
N
R.E.& R. SB-10-98

Fig. 6
2 of 2

APPENDIX

HISTORICAL DATA ON ELBOW RIVER FLOODS

A search of old newspapers and of the files of the Federal Water Resources Branch in Calgary revealed a wealth of information, both quantitative and descriptive, about floods on the Elbow River as far back as 1915 and the occasional reference to rampaging water previous to that.

This appendix is composed of five parts:

A. Short excerpts (quotes and/or paraphrases) from the pages of Calgary newspapers describing flood conditions.

B. Photographs of past floods from the files of the Federal Water Resources Branch in Calgary.

C. High water elevations of Elbow River flood waters in 1915 and 1923 from the files of the Federal Water Resources Branch in Calgary.

D. Hourly data on major Elbow River floods from the files of the Federal Water Resources Branch in Calgary.

E. Several pertinent letters from the files of the Alberta Department of Water Resources in Edmonton, including the preliminary report on this study.

APPENDIX A

Newspaper Reports of Past Floods

1897 - June 24 Edition of the Weekly Herald

1. Flood in early morning of June 20th.
2. Elbow River rose 4½ feet in ½ hour.
3. Calgary's greatest flood occurred in 1879.
4. Railway bridge over Elbow washed away twice in 1884.

1915 - June 26 Edition of the Calgary Herald

1. Water flooded to within a few inches of top of arches of new Mission Bridge.
2. Water has covered the lots of the following people:

J.K. Cummings - 333 - 40 Ave. West
A.C. Russell - 319 - 40 Ave. West
F.H. Peters - 709 Sifton Boulevard
G.S. Orde - 802 Riverdale
Dr. R.B. O'Callaghan - 822 Riverdale
W.H. Clark - 1302 Riverdale
Archie McKillop - 722 Riverdale

- June 28 Edition of the Calgary Herald

1. Water 2 feet deep near a house at 409 - 40th Ave. West in Elbow Park.
2. Pictures of flood conditions during peak printed in June 28, 1915 edition.
3. Water approximately 1 foot deep at 327 - 40th Ave. West

1923 - June 1 Edition of the Calgary Herald

1. Basement of City power house flooded (that was in the present Exhibition Grounds).
2. Low lying property in Elbow Park and East Mission covered with running water.
3. Most houses on either side of 40th Ave. completely surrounded by running water; avenue a raging torrent.

4. Exceeds 1915 mark by 6 inches to 8 inches.

5. Four feet of water flowing down 40th Ave. (no time given).

6. At 6th Street West and 30th Ave. river has risen over banks and is flowing through back yards. At 38th Ave. the stream has burst its bank.

7. Scores of houses from 38th Ave. to 40th Ave. from 4th Street to the river are altogether cut off.

8. Rideau Park - water to back entrance of all houses along river bank.

9. Roxboro Place - houses on street nearest river surrounded.

10. 26th Ave. West of 3rd Street - Ferguson's house surrounded (106 - 26th Avenue West).

11. Rivermede Apartment in midst of torrents (124 - 26th Ave).

12. Houses on 25th Ave. on both sides of river surrounded.

13. "If water rises 1 more foot it will back up against steel plating on girders".

14. Water within a few inches of top tiers of Mission Bridge.

1929 - June 3 Edition of the Calgary Herald

1. Every house between 40th and 25th Ave. along river affected.

2. 12th Ave. East - Sunshine Auto Camp under 6 feet of water (location across from Stampede Grounds near old hydrometric gauge).

3. C.N.R. freight yard line washed out.

4. Entire Mission district, Roxboro, and portions of Rideau and Riverdale under water.

5. Water lapping over floorboards of 12th and 9th Ave. Bridges

6. At 1:30 P.M. Monday the Elbow Broke loose near the car barns (in the vicinity of the old city power pland and flooded the 2nd Street East subway).

7. Every house facing the river from Mission Bridge to the 25th Ave. bridge and right north almost to the 2nd Street East bridge sustained damage.

8. The roadway which adjoins two bridges at 9th Ave. and 8th Street East was completely under water.

9. "Debris in front of 25th Ave. bridge caused the waters to back up to the yards on 1st Street and at 2:00 P.M. the water had reached the roadway and was pouring down in a steady stream to the drain at the bottom of the hill".

June 4 Edition of the Calgary Herald

1. Water nearly to roof of 2nd Street East C.N.R. subway.

2. 2nd Street East and 20th Ave. - waterfall where a torrent washed away part of embankment (over bank flow).

3. Center span of 25th Ave. S.E. bridge washed out.

June 4 Edition of the Calgary Albertan

1. "Rideau Park in a better condition than most low-lying land.

2. "Roxboro sorry spectacle, original course of Elbow could not be discerned".

3. "Victoria Park a flat lake". (Exhibition Grounds)

4. "Elbow Park a watery wilderness".

5. Districts worst affected along Elbow River - Elbow Park, Roxboro, and Victoria Park.

6. 24th and 26th Avenues flooded up to 2nd Street West.

7. On 25th Ave. all houses flooded but water did not reach the street level several feet higher.

8. Near intersection of 1st Street West the flood crept over a low bank and flooded cellars and yards along 26th Ave.

9. Breaking over banks opposite 27th Ave. East the river forced its way down 1st Street East to 26th Ave. east of the river and following the avenue to 2nd Street, finally flooded into the C.N.R. subway.

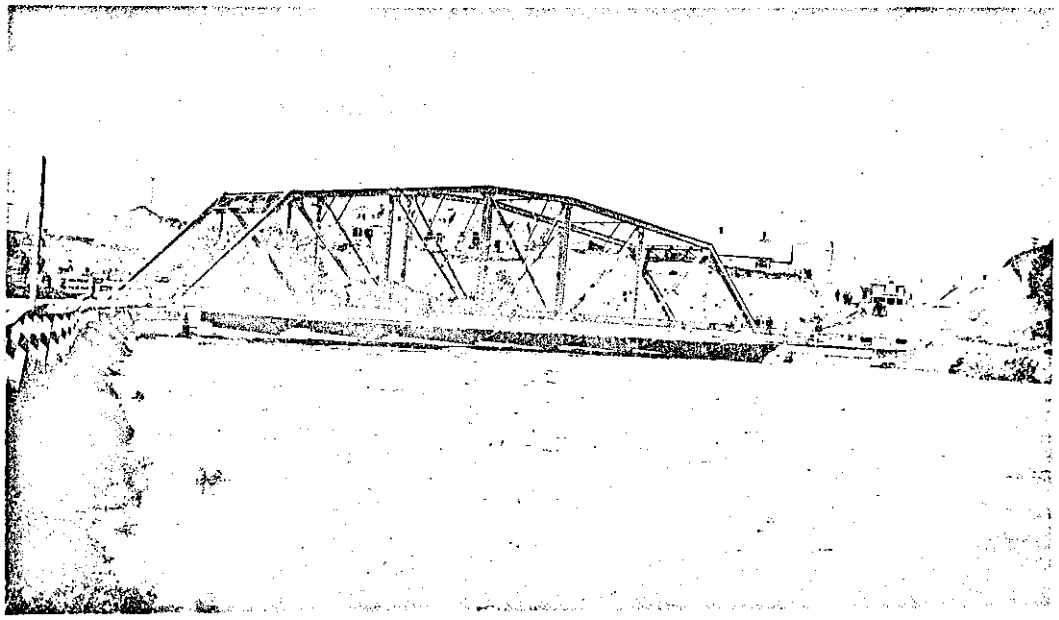
10. River covered a large tract of C.N.R. land between the river and 2nd Street East. North of tracks the water surrounded the freight sheds and tool houses and reached the subway.

1932 - June 3 Edition of the Calgary Herald.

1. "Encircled by approximately 6 feet of water on the south side and to a depth of 12 feet on the west, the City Auto Camp on the McLeod Trail (40th Ave. S.W. east bank of river) was transformed into an island."

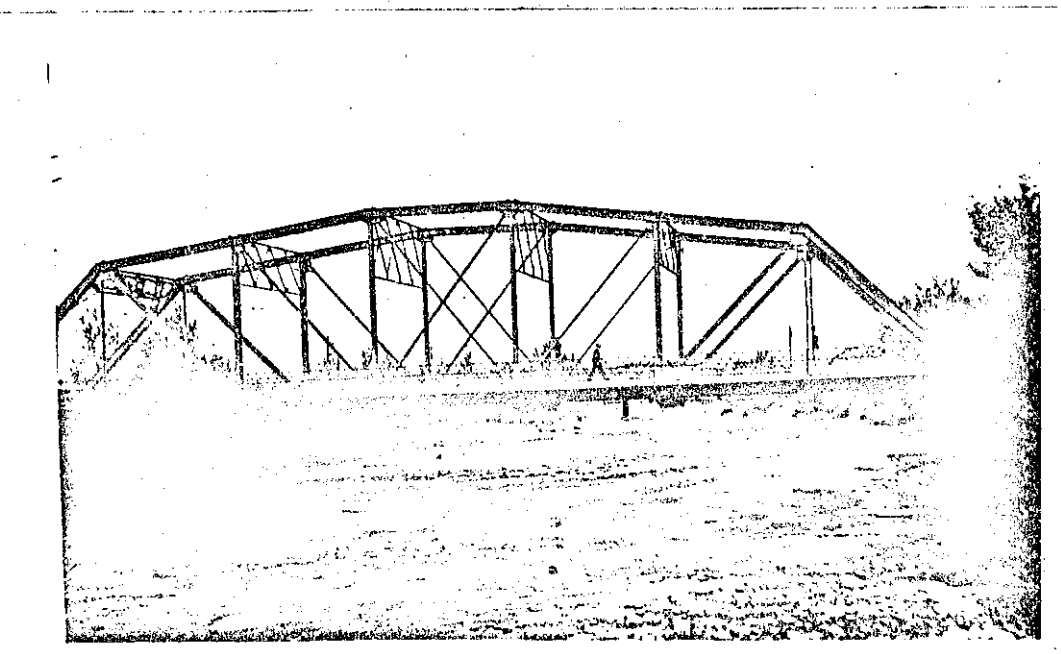
APPENDIX B

The Pictorial Record



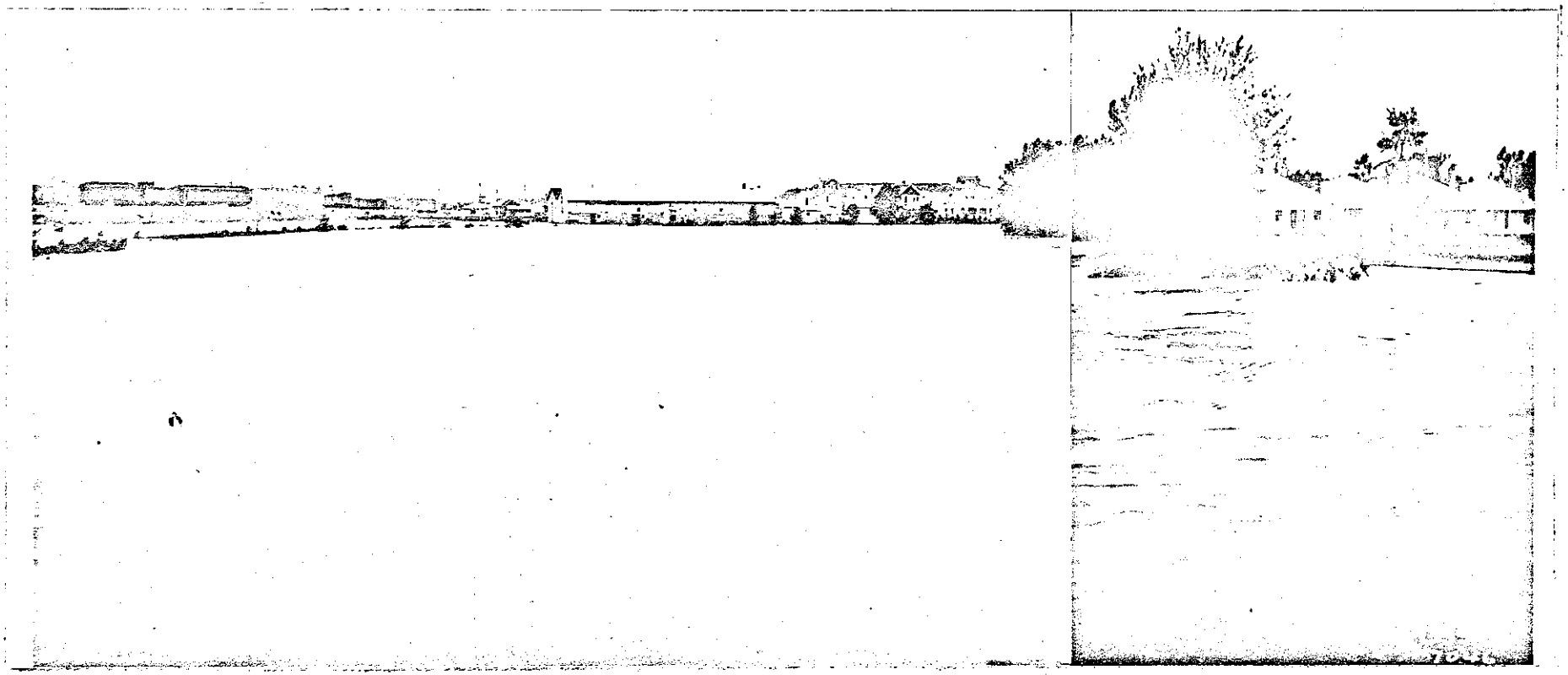
R.E.D.R.58-10-11B

12th Ave. bridge in high and low water. The picture above was taken at 5:05 P.M. June 26, 1915 about an hour after the peak had passed. The bottom picture, shown here for comparison, was taken September 12th, 1928.



R.E.D.R.58-10-12B

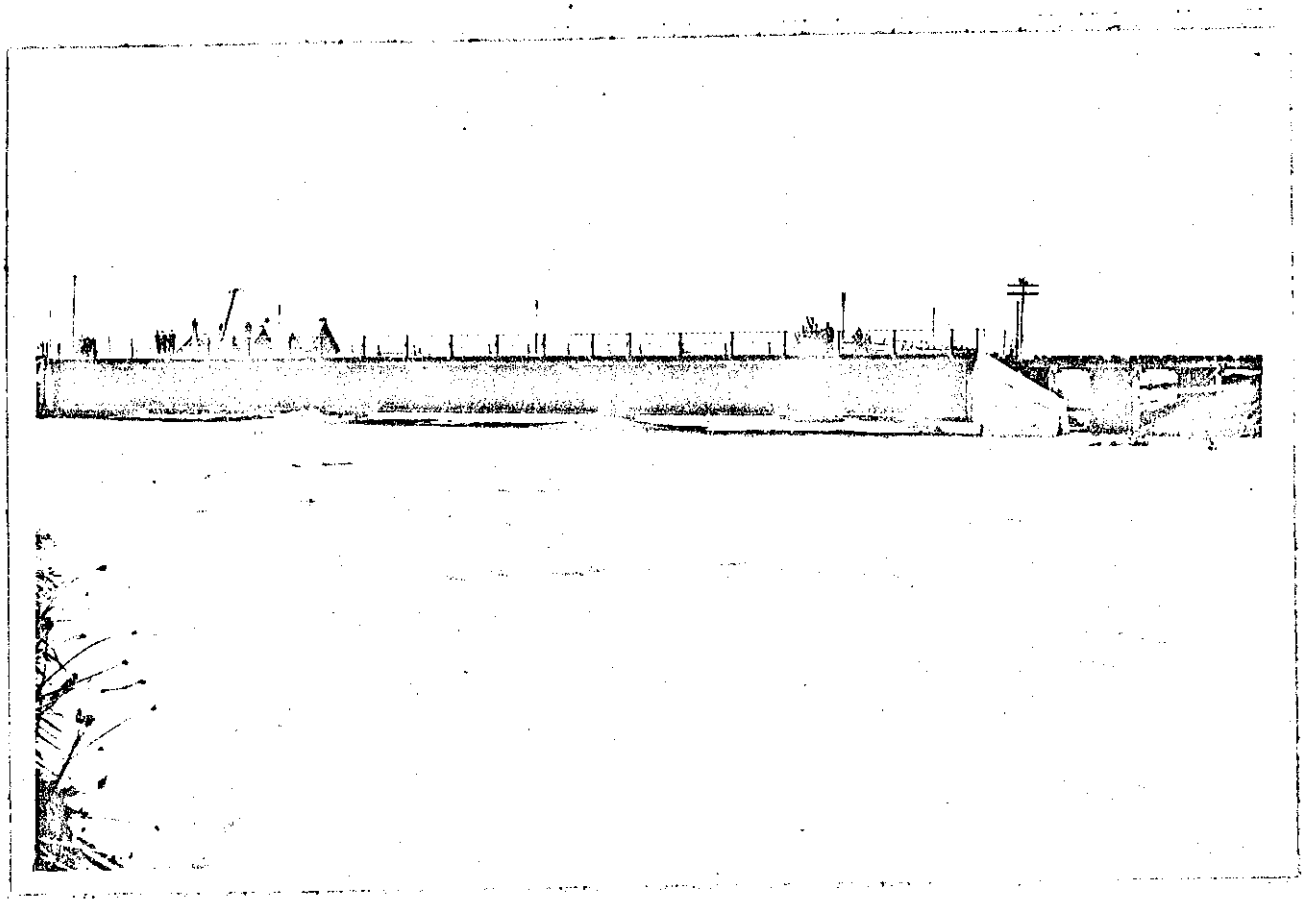
R.E.O.R.SB-10-13B



1915

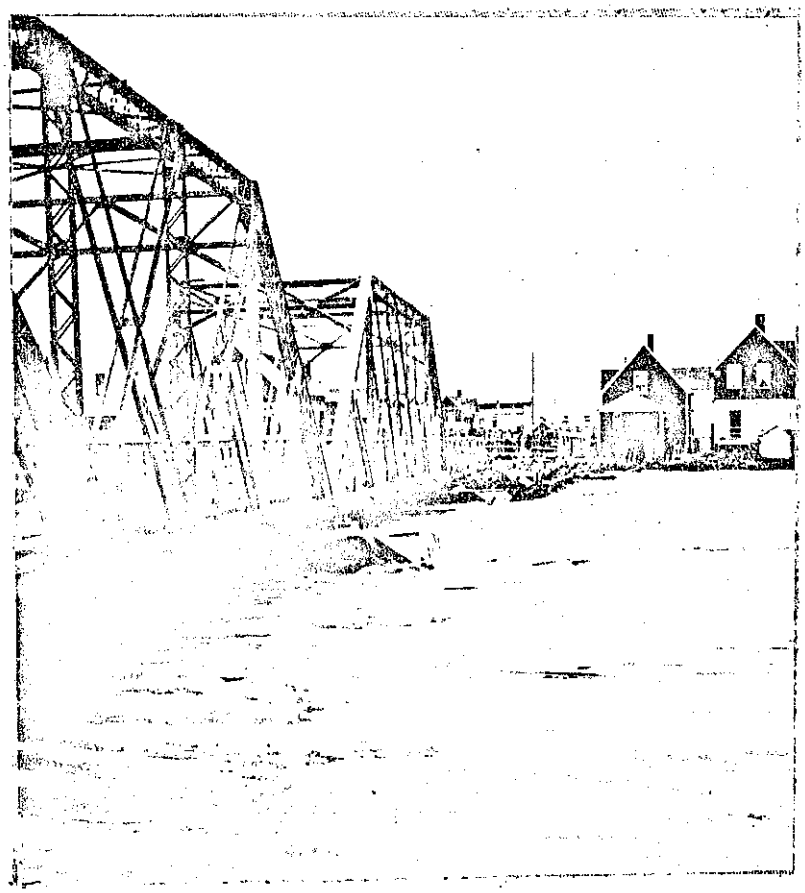
Looking upstream from Holy Cross hospital at 4 P.M. June 26, 1915 near flood peak.

R.E.O.R.58-10-148



1915

R.E.O.R.58-10-153

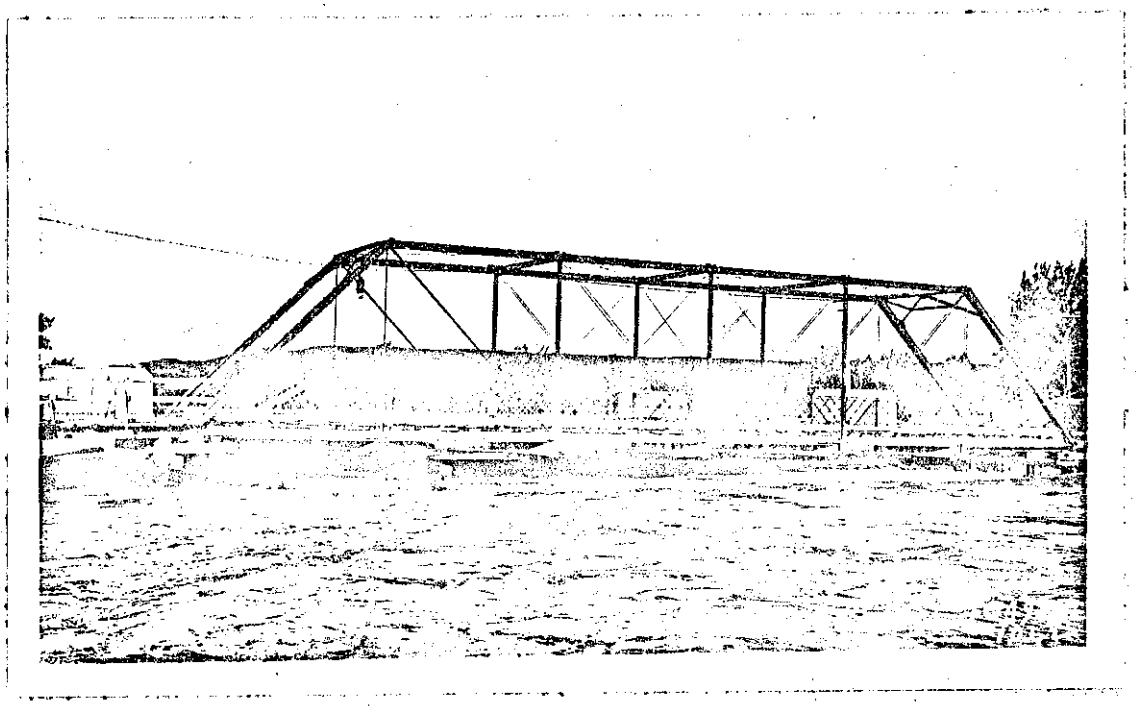


▲ C.N.R. bridge looking downstream from north bank of river near peak flow. 4:15 P.M. June 26, 1915.

◀ 25th Ave. bridge looking east. 4:45 P.M. June 26. 1915

1915

R.E.o.R.58-10-168



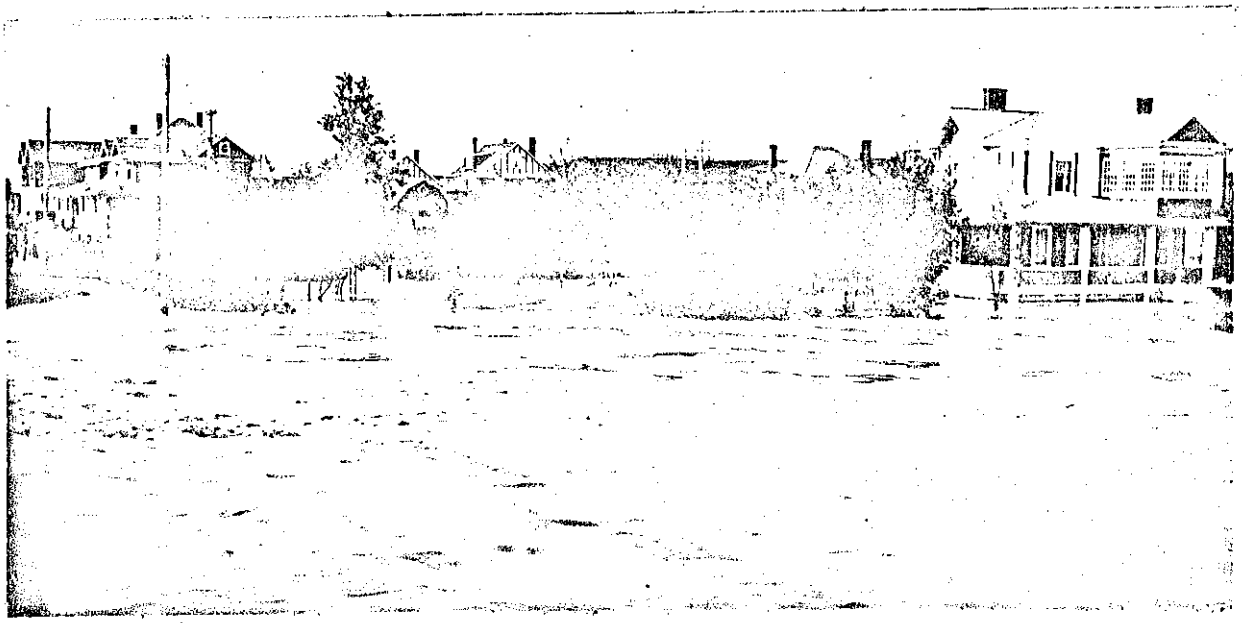
A

Old Mission Bridge 6:30 P.M. June 26, 1915

Judge McCarthy's house taken from Elboya Bridge 5:20 P.M.

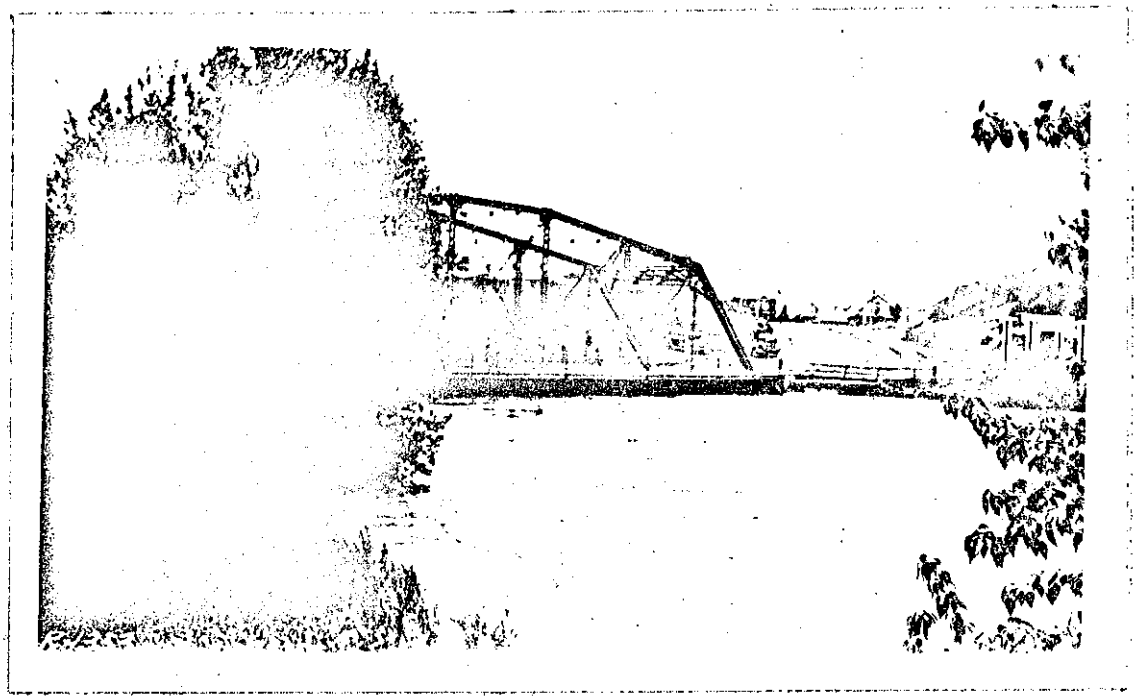
V

R.E.o.R.58-10-178



1929

R.E.O.R.58-10-18B



A

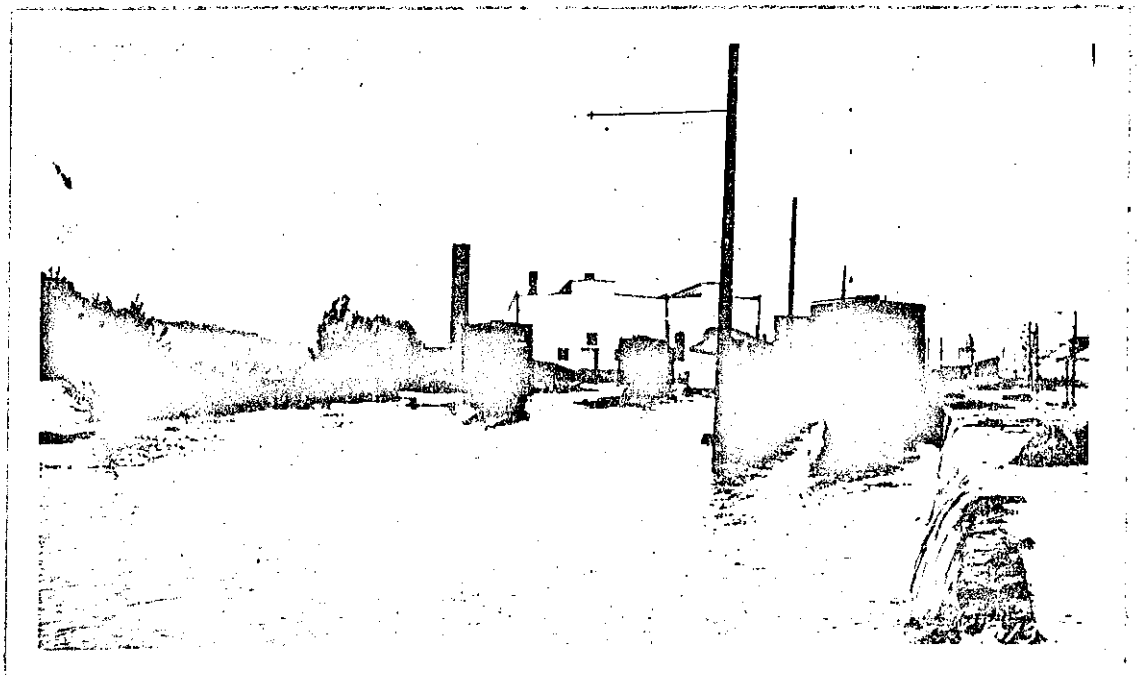
12th Ave. bridge at peak flow June 3, 1929, gauge height 11.9'

Q = 15,300 c.f.s.

Flooding at city power house June 3, 1929, gauge height 11.8'

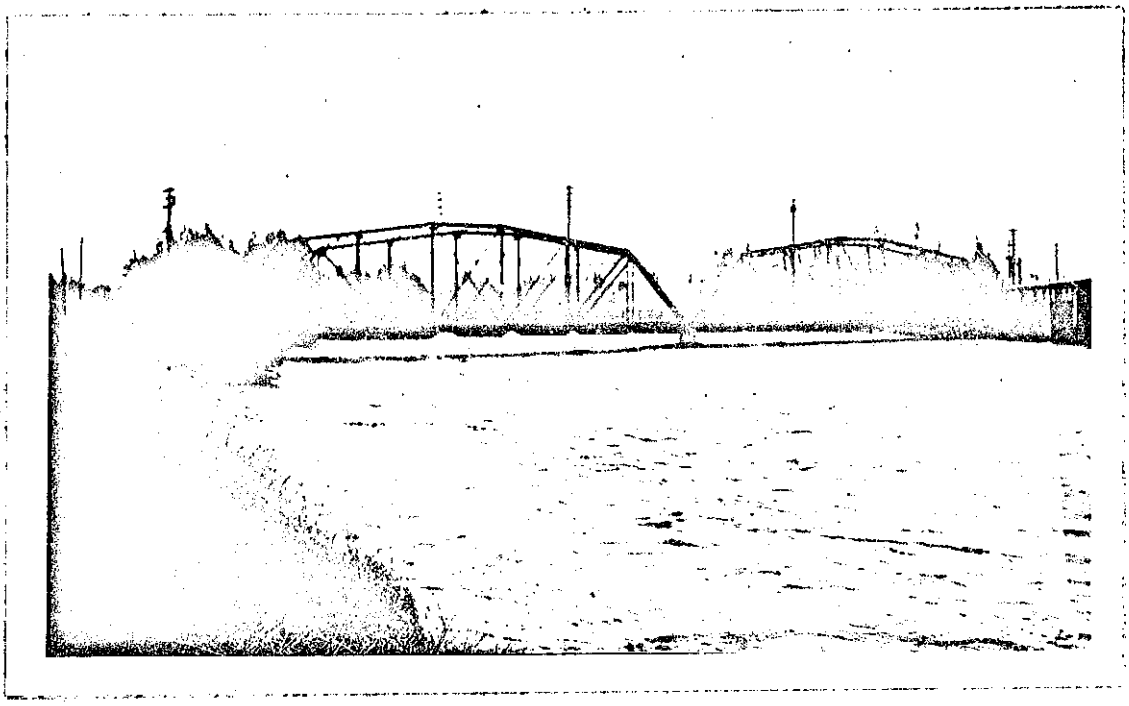
V

R.E.O.R.58-10-19B



1929

R.E.O.R.513-10-208

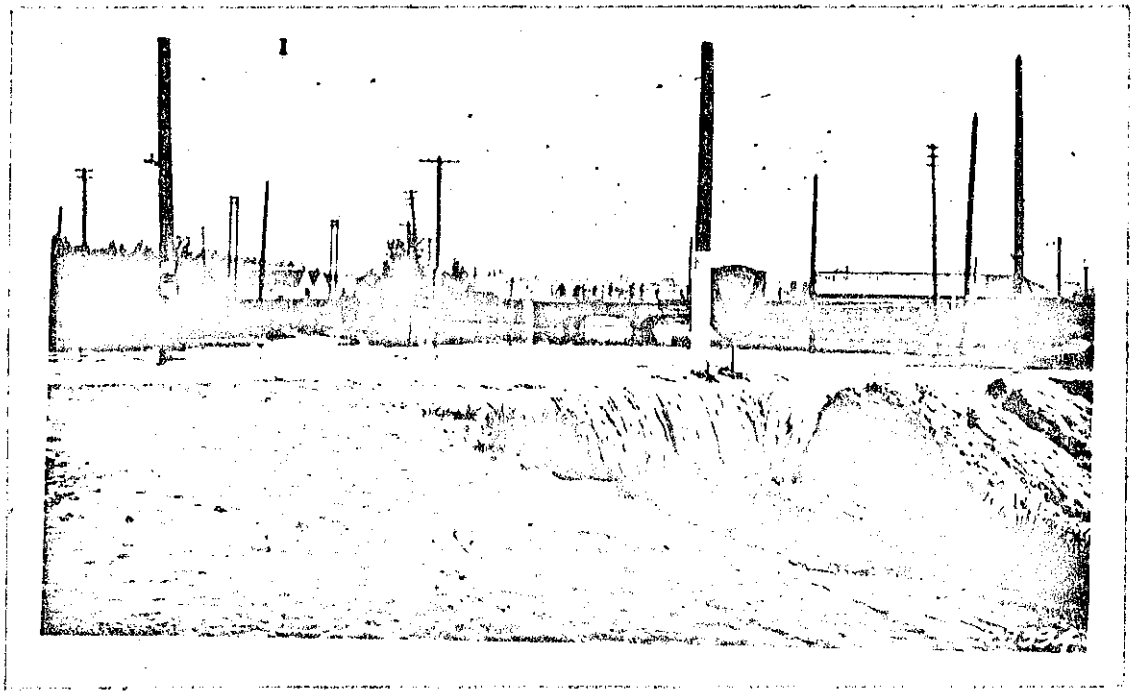


2nd St. East bridge near peak June 3, 1929

Overflow through 2nd St. East subway returning to Elbow River

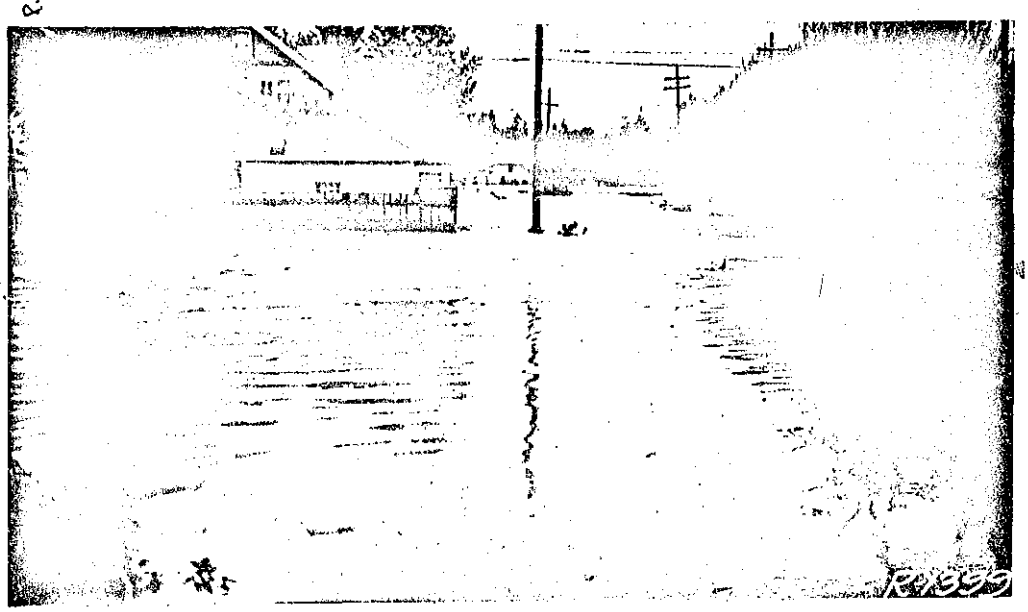
June 3, 1929, gauge height 11.7'

R.E.O.R.58-10-218



1929

R.E.O.R.58-10-228

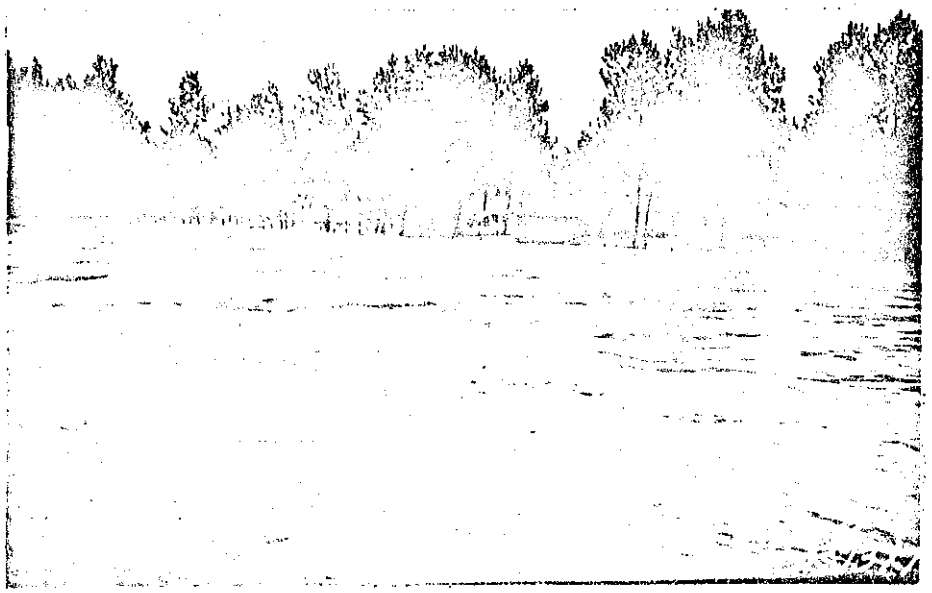


1st St. S.W. looking south from 25th Ave. June 3, 1929.

R.E.O.R.58-10-238

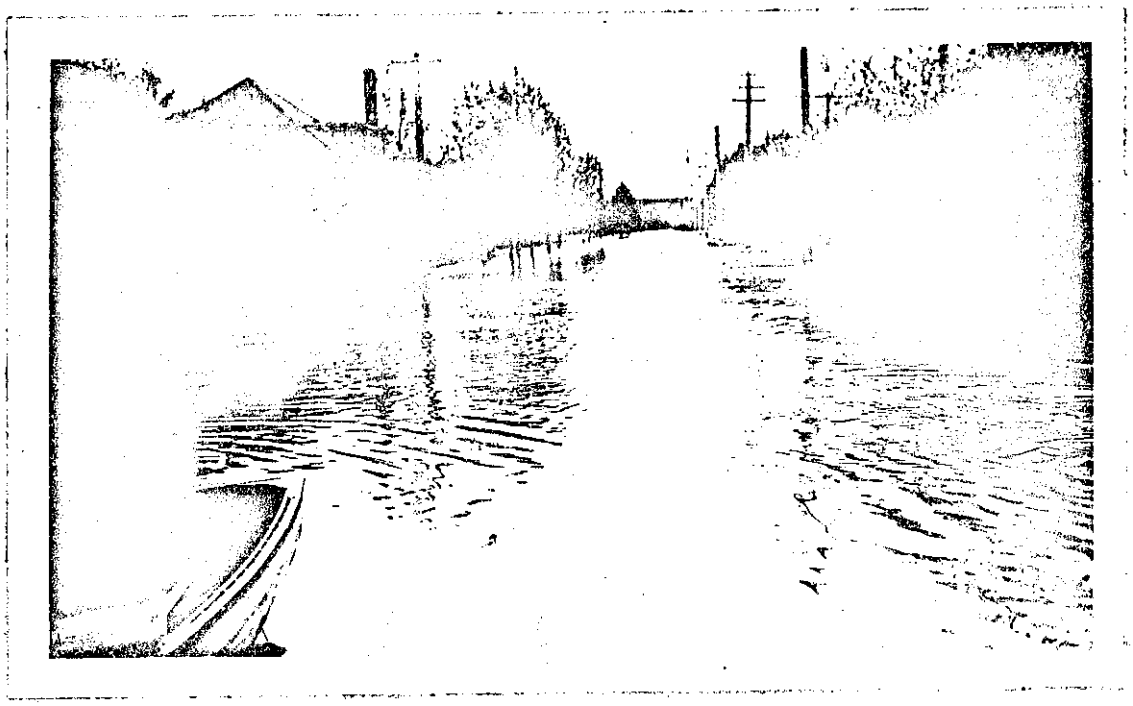
Mission Bridge
Gauge height 11.5'
June 3, 1929.

R.E.O.R.58-10-248



Rideau Park from across the Elbow River near 32nd Ave.

1929



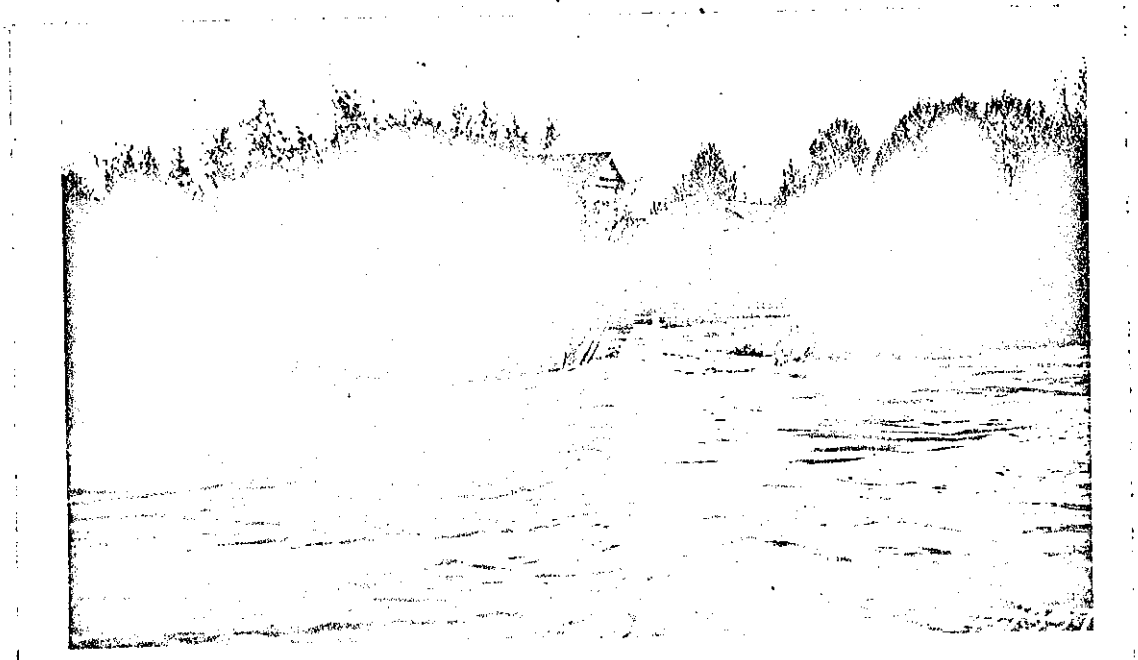
R.E.O.R.58-10-238

▲

40th Ave. east of 6th St. W. near peak flow June 3, 1929

Looking northeast from 6th St. W. bridge June 3, 1929

▼



R.E.C.R.58-10-268

APPENDIX C

RECORDED FLOOD PROFILES

1. High Water Elevations of Elbow River Flood on June 26th, 1915

13,400 c.f.s.

Elevations on left or north bank of Elbow

Location	Chainage ft.	Elevation (City Datum) ft.
G.T.P. Rly. Bridge	0	3377.14
9th Ave. E. Centre line of bridge	630	3377.80
C.P. Rly. main line bridge	775	3378.37
12th Ave. E. Bridge	1600	3379.17
12th Ave. E.	1900	3380.24
13th Ave. E.	2300	3380.30
14th Ave. E.	2700	3380.82
15th Ave. E.	3050	3381.64
17th Ave. E.	3300	3381.69
In Victoria Park 600	3900	3382.40
" by boiler Rm. 550	4450	3384.00
" by pump house 350	4800	3384.42
" 500	5300	3384.88
" 1000	7300	3385.76
" 500	7700	3387.87
" 500	8200	3388.98
C. Victoria Bridge 2nd St. E. 500	8730	3390.76
1st Street E.	9400	3394.40
Centre St.	10,000	3396.41
Centre C.N.R. Bridge 1st St. W.	10,400	3399.02
Bet. 19th and 21st Aves.	10,800	3399.87
21st ave.	11,100	3400.24
22nd Ave.	11,300	3400.87

Location	Chainage ft.	Elevation (City Datum) ft.
23rd Ave.	12,200	3402.06
24th Ave.	12,600	3402.24
C. of 25th Ave. Bridge	12,950	3403.65
26th Ave.	13,400	3404.58
1st St. W.	14,200	3406.11
2nd St. W.	14,800	3407.13
Bet. 2nd & 4th Strs. W.	15,000	3408.44
4th St. W.	15,340	3409.65
5th St. W.	15,700	3410.93
Carden Creseent	16,350	3410.54
Near 29th Ave.	16,600	3412.11
	500	3412.52
	510	3412.81
34th Ave.	18,400	3412.84
36th Ave.	19,000	3414.66
37th Ave.	19,500	3415.00
4th St. looking north	20,000	3415.19
3rd St. W. looking north	20,350	3416.39
do do south	21,300	3416.23
4th St. W. do do	21,700	3417.42
4A St. W.	22,300	3418.22
	375	3418.43
C. line of 6th St. Bridge	23,290	3420.04
Near 7th St. W.	24,000	3421.15
Near 8th St. W.	24,600	3421.90
Between 8th & 9th St. W.	25,000	3423.00
Between 9th & 11th St. W.	25,500	3423.78
11th St. W.	26,000	3424.27

2. High Water Elevations of Elbow River Flood on June 1st, 1923

13,900 - 14,200 c.f.s.

Elevations on left or north bank of Elbow

Location	Chainage	Elevation (City Datum) ft.	Gauge Height ft.
12th Ave. E. Bridge	1550	3379.91*	10.34
13th Ave. E.	2300	3381.08*	10.34
25th Ave. bridge (just above)	12,950	3405.71*	10.34
Mission Bridge Downstream Side			
at centre N. span	15,340	3409.11	10.26
at N. mid. span		3408.80	
at S. span		3409.04	
25' downstream S. shore		3409.06	
75' " S. shore		3408.47	
25' " N. shore		3408.91	
100' " N. shore	15,240	3408.52	
Mission Bridge Upstream Side			
at centre N. span	15,340	3409.59	
at centre N. mid span		3409.25	
at centre S. span		3409.28	
25' upstream N. shore		3410.03	
100' " N. shore	15,440	3410.77	
300' " N. shore	15,640	3411.40	
25' " S. shore		3409.47	
120' " S. shore	15,460	3409.63	10.26

Elevations marked * are maximum stage.

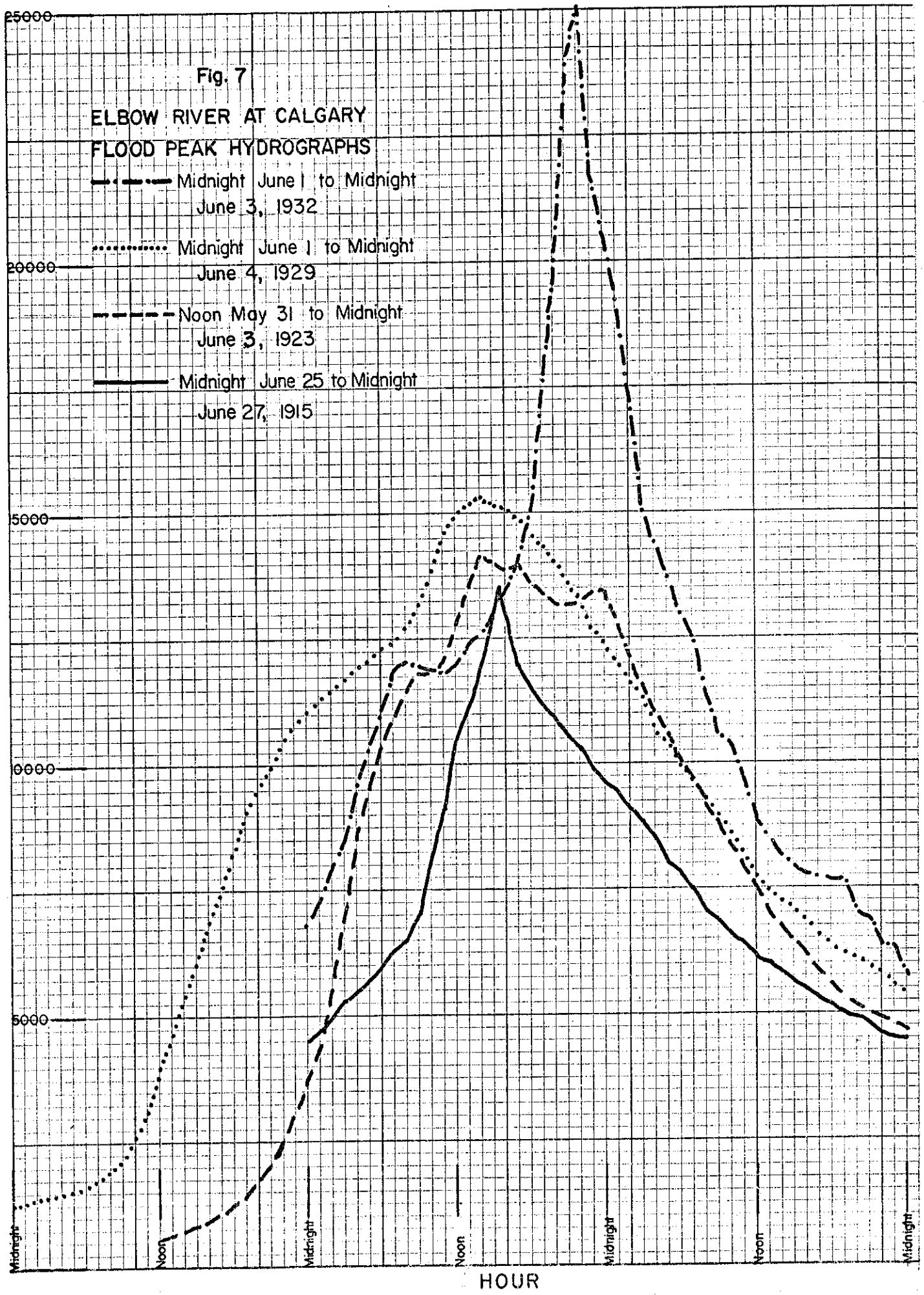


Fig. 7
ELBOW RIVER AT CALGARY
FLOOD PEAK HYDROGRAPHS
Midnight June 1 to Midnight June 3, 1932
Midnight June 1 to Midnight June 4, 1929
Noon May 31 to Midnight June 3, 1923
Midnight June 25 to Midnight June 27, 1915
25000
20000
15000
10000
5000
Discharge in cubic feet / second
Midnight
Noon
Midnight
Noon
Midnight
Noon
Midnight
HOUR

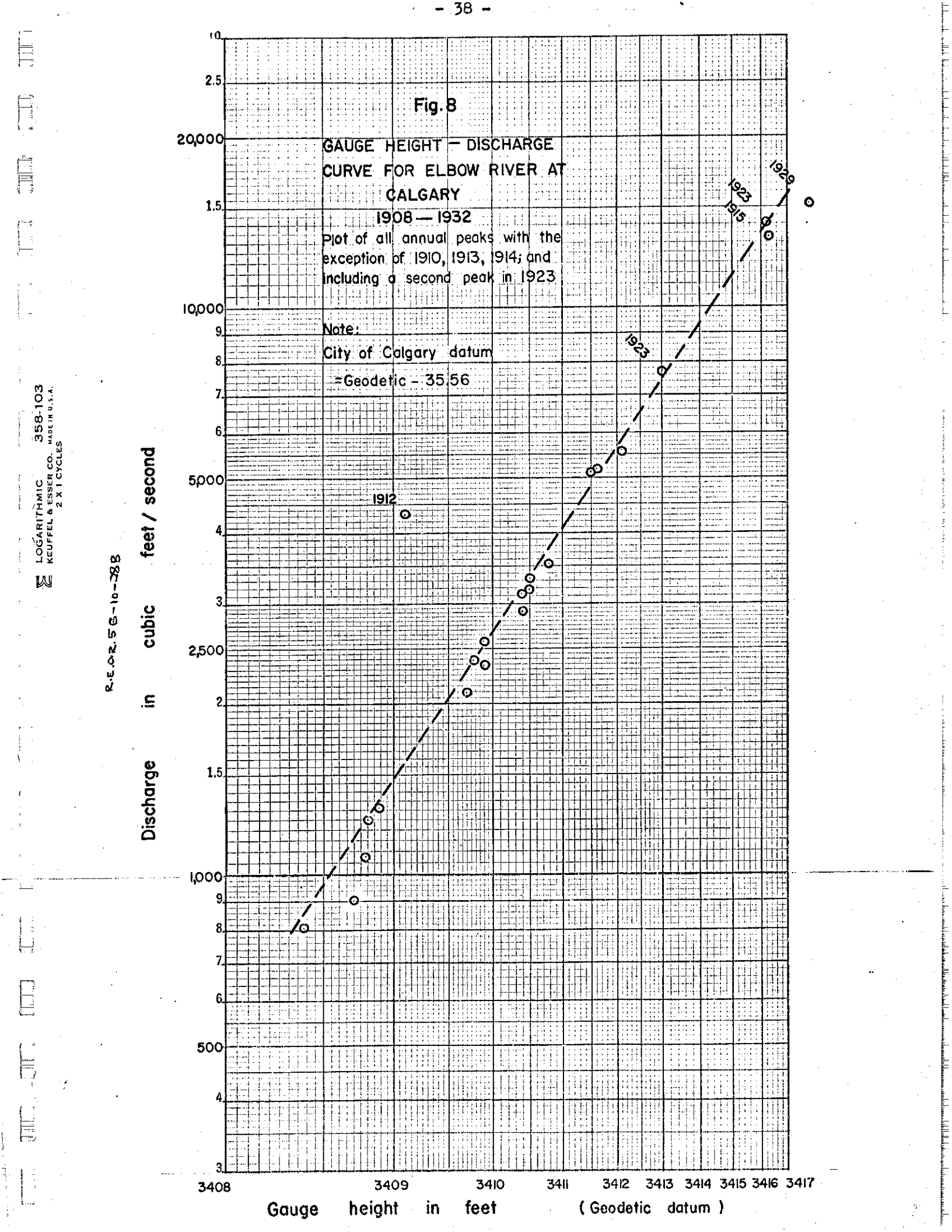


Fig. 8
GAUGE HEIGHT — DISCHARGE CURVE FOR ELBOW RIVER AT CALGARY
1908 — 1932
Plot of all annual peaks with the exception of 1910, 1913, 1914; and including a second peak in 1923
Note:
City of Calgary datum
=Geodetic - 35.56
1912
1915
1923
1923
1929
Discharge in cubic feet / second
Gauge height in feet (Geodetic datum)
3408
3409
3410
3411
3412
3413
3414
3415
3416
3417
10
2.5
20,000
1.5
10,000
9
8
7
6
5,000
4
3
2,500
2
1.5
1,000
9
8
7
6
500
4
3
LOGARITHMIC 358-103
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 X 1 CYCLES
R.E.O.R. 5-6-10-38

APPENDIX D

Hourly Data on Major Elbow River Floods.

Hourly Gauge Height and Discharge in cubic feet per second of Elbow River at Calgary during flood caused by storm of May 30 to June 1, 1923.

Hour	May 31		June 1		June 2		June 3	
	Gauge Height	Dis-charge	Gauge Height	Dis-charge	Gauge Height	Dis-charge	Gauge Height	Dis-charge
1	1.68	388	5.25	4,430	9.70	12,800	5.32	4,540
2	1.68	388	5.95	5,600	9.32	12,000	5.27	4,460
3	1.68	388	6.80	7,130	9.04	11,500	5.20	4,350
4	1.69	392	7.60	8,650	8.80	11,000	5.15	4,270
5	1.69	392	8.10	9,600	8.54	10,500	5.10	4,190
6	1.71	402	8.50	10,400	8.34	10,100	5.03	4,080
7	1.75	422	8.80	11,000	8.13	9,660	4.97	3,980
8	1.80	447	9.07	11,500	7.88	9,180	4.92	3,900
9	1.83	463	9.20	11,800	7.67	8,780	4.87	3,820
10	1.91	506	9.22	11,800	7.40	8,270	4.82	3,740
11	2.00	558	9.32	12,000	7.20	7,890	4.77	3,660
12	2.10	618	9.70	12,800	6.98	7,480	4.73	3,600
13	2.20	679	10.08	13,600	6.78	7,100	4.68	3,520
14	2.30	743	10.34	14,200	6.59	6,740	4.64	3,450
15	2.42	824	10.30	14,000	6.40	6,400	4.60	3,390
16	2.60	960	10.22	13,800	6.22	6,080	4.56	3,330
17	2.77	1,100	10.30	14,000	6.06	5,790	4.52	3,270
18	2.93	1,250	10.10	13,600	5.91	5,530	4.48	3,210
19	3.15	1,450	10.00	13,400	5.81	5,360	4.45	3,160
20	3.48	1,800	9.88	13,200	5.71	5,200	4.40	3,090

Continued....

Hour	May 31 Gauge Height	May 31 Dis-charge	June 1 Gauge Height	June 1 Dis-charge	June 2 Gauge Height	June 2 Dis-charge	June 3 Gauge Height	June 3 Dis-charge
21	3.75	2,140	9.88	13,200	5.62	5,030	4.36	3,030
22	4.04	2,550	9.90	13,200	5.54	4,900	4.33	2,980
23	4.40	3,090	9.98	13,400	5.48	4,780	4.30	2,940
24	4.87	3,820	10.00	13,400	5.40	4,670	4.27	2,900
Mean[a]		1,070		11,700		7,780		3,660
Run-off Acre-feet		2,122		23,207		15,431		7,260

a. - Mean shown is true mean for day, not mean of hourly readings shown herewith.

Mean Hourly Gauge Height and Discharge in cubic feet per second of Elbow River at Calgary during flood caused by storm of May 31 to June 3, 1929.

Hour	June 2		June 3		June 4		June 5		June 6	
	Gauge Height	Dis-charge	Gauge Height	Dis-charge	Gauge Height	Dis-charge	Gauge Height	Dis-charge	Gauge Height	Dis-charge
1	3.16	1,370	9.52	11,300	9.90	12,000	5.90	5,200	4.76	3,310
2	3.19	1,400	9.62	11,500	9.66	11,600	5.80	5,030	4.74	3,280
3	3.22	1,430	9.75	11,700	9.40	11,100	5.71	4,880	4.72	3,250
4	3.28	1,480	9.85	11,900	9.17	10,700	5.62	4,730	4.70	3,220
5	3.36	1,550	9.96	12,100	8.93	10,300	5.54	4,590	4.68	3,200
6	3.46	1,650	10.08	12,300	8.71	9,950	5.48	4,490	4.65	3,150
7	3.58	1,770	10.18	12,400	8.52	9,630	5.42	4,390	4.63	3,120
8	3.76	1,970	10.32	12,700	8.31	9,270	5.39	4,340	4.61	3,090
9	3.95	2,200	10.62	13,200	8.10	8,920	5.33	4,240	4.59	3,070
10	4.31	2,680	11.00	13,800	7.90	8,580	5.30	4,190	4.57	3,040
11	4.68	3,200	11.45	14,600	7.67	8,190	5.27	4,140	4.55	3,010
12	5.18	3,980	11.70	15,000	7.39	7,720	5.22	4,050	4.53	2,980
13	5.56	4,630	11.84	15,200	7.22	7,430	5.18	3,980	4.50	2,940
14	6.02	5,400	11.89	15,300	7.11	7,240	5.12	3,880	4.49	2,930
15	6.42	6,080	11.84	15,200	7.00	7,060	5.06	3,780	4.47	2,900
16	6.86	6,820	11.73	15,100	6.85	6,810	4.98	3,650	4.45	2,870
17	7.25	7,480	11.61	14,900	6.70	6,550	4.93	3,470	4.42	2,830
18	7.75	8,330	11.49	14,600	6.59	6,370	4.90	3,520	4.40	2,800
19	8.25	9,170	11.29	14,300	6.50	6,220	4.89	3,500	4.39	2,790
20	8.50	9,600	11.09	14,000	6.42	6,080	4.88	3,490	4.38	2,770

continued.....

Hour	June 2 Gauge Height	June 2 Dis-charge	June 3 Gauge Height	June 3 Dis-charge	June 4 Gauge Height	June 4 Dis-charge	June 5 Gauge Height	June 5 Dis-charge	June 6 Gauge Height	June 6 Dis-charge
21	8.72	9,970	10.85	13,600	6.35	5,960	4.85	3,440	4.37	2,760
22	9.01	10,500	10.61	13,200	6.25	5,790	4.82	3,400	4.35	2,730
23	9.21	10,800	10.35	12,700	6.13	5,590	4.80	3,370	4.33	2,710
24	9.39	11,100	10.15	12,400	6.02	5,400	4.78	3,340	4.32	2,690
Total		124,560		323,000		194,460		97,090		71,440
Mean		5,190		13,500		8,100		4,050		2,980

APPENDIX E

Letters from the files of the

Alberta Department of Water Resources

including the Preliminary Report

THE CITY WILL NOT BE RESPONSIBLE FOR MATERIALS SUPPLIED UNLESS WRITTEN ORDERS HAVE BEEN GIVEN BY THE CITY'S PURCHASING AGENT

City of Calgary

WATERWORKS DIVISION

ENGINEER
[redacted], M.E.I.C.
W. J. ROY, P. ENG.

ENGINEERING DEPARTMENT

Calgary, Alberta, Canada
June 30, 1959.

Government of Province of Alberta
Water Resources Branch,
Terrace Building,
EDMONTON, Alberta.

Attention: Mr. J.L. Reid

Dear Sir:

Over the past several years there has been a gradual encroachment of the Elbow River watercourse downstream of the Glenmore Dam and within the City limits.

This is beginning to cause us considerable difficulty whenever we are required to discharge downstream flows exceeding 1500 c.f.s. Our latest experience with a discharge of some 2100 c.f.s. has resulted in several citizen complaints concerning the flooding of backyard patios, fences, shrubs, lawns, etc.

As you are no doubt aware, probable downstream river flows at some future date could greatly exceed these present flows, and we are somewhat concerned over the damage that may result from this continued encroachment. We would therefore appreciate your taking this matter under study to determine the possibilities of maintaining the original watercourse and restricting further development of this kind.

We would be pleased to receive your comments on this matter.

Yours truly,

A. H. Nicolson
CITY ENGINEER.

CTW/op

COPY

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES

Water Resources Branch

Office of the District Engineer

423 Public Building,
Calgary, Alberta,
14 February 1961.

Mr. J.L. Reid,
Dept. of Water Resources,
Province of Alberta,
Brock Building,
10177 - 104 Street,
EDMONTON, Alberta.

Elbow River below Glenmore Dam

Dear Mr. Reid:

Mr. Barnetson informs me that you were interested in the flood possibilities on a flat on the right bank of the Elbow River opposite the Holy Cross Hospital. We are submitting herewith certain photographs taken at or near the site in question during the 1915 and 1929 floods on this stream. You will also be interested in the data and comments herein.

The enclosed photographs are the following:

No. 7034 - 4:15 p.m., 26 June 1915 - looking across the flat in question toward the Holy Cross Hospital. This picture is believed to have been taken very near the peak of the 1915 flood and you will note that the flat is under water (perhaps 2 feet deep? - note wagon wheel).

No. 7049 - 4:15 p.m., 26 June 1915 - looking downstream to C.N.R. bridge from right bank. The bridge is close below the flat in question. We believe that this picture was also taken close to the 1915 peak. We used this picture to determine the water elevation for the 1915 flood as given below.

See Appendix B
Page 3

No. 7044 - 4:40 p.m., 26 June 1915 - upstream side of 25 Ave. Bridge, not far above the flat in question. This picture also probably taken near the peak of the 1915 flood.

No. R-1396 - 3 June 1929 - downstream side of 25 Ave. Bridge near peak of 1929 flood. Note that the water level is very similar to that for the 1915 peak.

Water elevation for 1915 peak (Reference: pictures 7034 & 7049)

We tied in the water level at the point on the bridge (shown on the right of picture 7049) to G.S.C. datum on 6 February 1961, using an elevation of a manhole cover given to us by the City of Calgary Engineering Dept. We found the elevation of the water at the time of the pictures to be 3431 G.S.C. There is a possibility that the time of the 1915 peak did not coincide exactly with these pictures and that the actual peak may have been as much as one foot higher but we believe that this is not the case and that the peak of the 1915 flood was probably 3431 G.S.C. at the C.N.R. bridge about one-quarter of a mile below the Holy Cross Hospital.

From the plans you have shown me it is apparent that the flats opposite the hospital and west of the C.N.R. grade reach about elev. 3401.44, City datum, or 3437 G.S.C. Picture 7034 indicates that there was at least 0.5 feet of water on these flats at their highest point during the 1915 flood. In other words, the 1915 flood apparently reached an elevation of 3437.5 G.S.C. on the flats in question. These data indicate a slope of about 6.5 feet during the 1915 flood between the Hospital and the C.N.R. bridge shown in picture 7049. These are only rough figures but they appear reasonable.

The pertinent data at the former gauging station (a little below the Holy Cross Hospital and near the 12 Ave. Bridge) for the four highest peaks since 1915 are as follows:

Year	Peak G.H.	Peak Discharge - cfs -
1915	10.40	13,400
	(Reference: picture 7034, 7044, 7049)	
1923	10.34	14,200
1929	11.98	15,300
	(Reference: picture R-1396)	
	- Glenmore dam and reservoir constructed -	
1932	9.89	11,290
	(Peak discharge entering Glenmore reservoir was 25,200 c.f.s.)	

It will be noted that the 1932 flood was the highest of the four floods but that the peak in that year in the vicinity under study was lower than for the other three because of the effect of storage in the Glenmore Reservoir (Approx. capacity 13,000 acre-feet). However, the Glenmore Reservoir was empty prior to the 1932 flood. It is very doubtful if the reservoir would have a similar modifying effect on a future flood of equivalent size and shape.

Assuming that the Glenmore Reservoir had been at one-half capacity prior to the 1932 flood, we estimate that the peak could have been modified from 25,200 cfs above the reservoir to 14,500 cfs or gauge height 10.7 feet at the gauging station below the Hospital. Such a modification would thus produce water levels in the neighborhood of the Hospital very similar to those experienced in the 1915, 1923 and 1923 and 1929 floods.

Our general conclusion would be that a recurrence of the 1932 flood could produce water elevations on the flats opposite the Holy Cross Hospital similar to those experienced in 1915, 1923 and 1929 and as depicted in the four photographs herewith. In other words, we would anticipate water elevations in the neighborhood of 3437.5 G.S.C. on the flats in question. It must be emphasized that the position of the storage in Glenmore Reservoir prior to the flood and the control procedure adopted at the Glenmore dam during the flood would have considerable bearing on water elevations in the reach below the dam. If little or no modification were achieved at Glenmore dam during a future flood of the 1932 magnitude, then we would anticipate water elevations of as much as 4.5 feet higher on the flats opposite the Hospital.

Yours very truly,

E.P. Collier,
District Engineer.

EPC/k
Encls.

Photos 7034, 7044 and R1396 are not included in this report. Photo 7049 is on page 3 of Appendix B.

OFFICE OF THE
CITY ENGINEER

City of Calgary

OUR FILE NO. .....

YOUR FILE NO. .....

Calgary, Alberta, Canada

August 28, 1962.

Mr. Inge Anderson
Supervisor Hydro-Electric Development
Government of the Province of Alberta
Terrace Building
EDMONTON, Alberta.

Re: Proposed Flow Study of Elbow River
from Glenmore Dam to the Bow River

Dear Sir:

During 1960 and 1961 we discussed with Mr. Reid, at some length, the potential problems that would be encountered in the event of a flood of the Elbow River. The problem is becoming more acute for two main reasons:

(a) Encroachment into the drainage channel by residents whose property abuts the river.

(b) The dam and reservoir can no longer be relied upon to effectively control a flood because of the ever increasing demands on the domestic water supply.

It was decided at the time that a planimetric survey of the river channel and adjacent areas would be carried out. The resulting contour maps would then be studied to determine the top water elevations along the channel under various possible flood flows.

Mr. Reid kindly offered to have his Department carry out this study for us when adequate contour plans were available.

We are therefore forwarding, under separate cover, one complete set of the aforementioned plans and will, of course, be pleased to forward additional sets, or any other information that may be required.

We are most grateful for your valued assistance with this most important project.

Yours very truly,

A. H. Nicolson
CITY ENGINEER

WmJR*op

YOUR FILE NO. [illegible]

CANADA

DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES

WATER RESOURCES BRANCH

OFFICE OF THE DISTRICT ENGINEER

423 Public Building,
Calgary, Alberta,
12 October 1962.

Mr. R. K. Deeprose,
Hydrologic Division,
Department of Water Resources,
Terrace Building,
106 St. & 96 Ave.,
EDMONTON, Alberta.

Elbow River at Calgary

Dear Mr. Deeprose:

We have extracted the following information regarding this to G.S.C. for the above station:

Gauges	Date Available	Datum	Gauge Work During:
Staff	1908 - 1915	3426.40	1908 - 1911
Chain	1912 - 1924	3409.77	1912 - 1924 Winter conditions 1915 - 1919
Staff	May 1915 - 1933	3405.90	Open water 1915 - 1923 All year 1924 - 1933.

The above datums may not correspond to the figures shown in some of the early Water Resources Papers because those shown here are calculated on the 1923 G.S.C. adjustment.

Yours very truly,

R. D. MAY,
District Engineer.

CMM/k

OFFICE OF THE
CITY ENGINEER

OUR FILE NO. .....

YOUR FILE NO. .....

The City of Calgary

Calgary, Alberta, Canada

July 8, 1963.

Mr. R. K. Deeprose
Department of Water Resources
Hydrology Division
Terrace Building
EDMONTON, Alberta.

Re: High Flow Elbow River -
June 30, 1963

Dear Mr. Deeprose:

Enclosed for your information is a brief summary of the high river flows which we experienced on June 30. The summary is self-explanatory and will probably be of some help with flood study you are presently carrying out.

Yours very truly,

C. D. Howarth
ACTING CITY ENGINEER

WmJR*op
Encl:

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COPY

Maximum Downstream Flow Elbow River 5:00 to 5:30 Sunday July 1, 1963

Flow over spillway - 0.65 ft. head over flashboard	750 cfs.
West Dow Valve - 4 ft. open	2450 cfs.
East Dow Valve - 3 ft. open	1900 cfs.
Two Turbines	200 cfs.
	5300 cfs.

The river level was up to the edge of the landscaping of properties on Lansdowne & Riverdale Avenues. It was within about 1½ ft. of the bottom of the girders of the 26 Avenue bridge and within about 9 inches of the footbridge at the Exhibition Grounds.

Elevation of concrete crest - 3492.42

Avg. elevation of top of flashboards - 3496.85

OFFICE OF THE
CITY ENGINEER

OUR FILE NO. 2029

YOUR FILE NO. .....

The City of Calgary

Calgary, Alberta, Canada

March 4, 1965.

Department of Water Resources
Government of the Province of Alberta
107 Street & 96 Avenue
Terrace Building
EDMONTON, Alberta.

Attention: Mr. J.L. Reid, Supervisor
Hydro-electric Development

Re: Flow Study of Elbow River

Dear Sir:

We are enclosing herewith a copy of a letter from Messrs V. Zay Smith Associates Limited, listing the times that various aerial photographs of the Elbow River channel were taken.

The river flows at the corresponding times was as follows:

July	26	10:20 to 11:10 A.M.	485 c.f.s.
	26	11:15 to 11:35 A.M.	490 c.f.s.
	26	4:50 to 5:15 P.M.	520 c.f.s.
	31	9:20 to 9:40 A.M.	1170 c.f.s.
August	1	4:50 to 5:05 P.M.	810 c.f.s.
	10	10:45 to 10:50 A.M.	275 c.f.s.

1961

This information will probably be useful in connection with the flow studies presently being carried out.

Yours very truly,

Wm. J. Roy, P.Eng.
WATERWORKS ENGINEER

WmJR*op
Encl:

COPY

PRELIMINARY REPORT

April 6, 1965.

Mr. C.D. Howarth, P.Eng.,
City Engineer,
Engineering Department,
City of Calgary,
Calgary, Alberta.

Dear Sir:

Re: Elbow River Flood Study

Under separate cover, we are forwarding (a) a profile sheet showing water levels on the Elbow during various possible floods and (b) a set of maps of the Elbow River valley on which are drawn the approximate boundaries between dry land and flooded areas for floods of 10%, 5%, and 2% frequency. These two documents together comprise a preliminary report on the Elbow River Flood Study which was begun by this office two and a half years ago in direct answer to a letter from your City Engineer dated August 28, 1962.

Although referred to as 'preliminary', the information here presented is complete and will not differ from that in the final report barring the discovery of errors in the meantime. It was thought that you would prefer not to wait for the final report now that this was available.

The final report will contain a description of the problem and the manner in which the study was carried out (including assumptions involved) and supporting evidence for the conclusion presented in the way of old records, newspaper accounts, etc. I do hope, however, that you will go ahead immediately with your own studies on the basis of the information on these sheets.

In the way of a short explanation, the assumption was made that the Glenmore Reservoir provides no control of flooding on the Elbow River. I might also note at this time that although the profile of the 1915 flood levels plot lower than the computed 10,000 c.f.s. and 15,000 c.f.s. lines would indicate that it should, extensive encroachment into the river channel since that time could very well account for this. Last summer's water surface profile survey of the 5,000 c.f.s. discharge was extremely helpful in defining the flow conditions which exist at the present time.

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The computations for water surface profile were not carried beyond station 30650 because there is a large discrepancy upstream of this point between the profile of the water surface taken from the original contoured maps and the 2,400 c.f.s. and 5,000 c.f.s. water surface profiles.

Once again, I wish to apologize for the length of time this study has taken. Because it was so long and involved day-to-day and month-to-month jobs had to take precedence over it. I sincerely hope that the Elbow will remain 'tame' for a year or two more while something is done to protect the hundreds of endangered residences. It should be pointed out, however, that the Elbow has not experienced anything approaching a major flood since 1932. This is highly uncommon and forces a hydrologist to expect that in the near future a sizeable flood is bound to occur.

Should there be any questions arising from this preliminary report, please feel free to write immediately. The final report may still be some time in preparation.

Yours truly,

R.K. Deeprose, P.Eng.,
Hydrology Division.