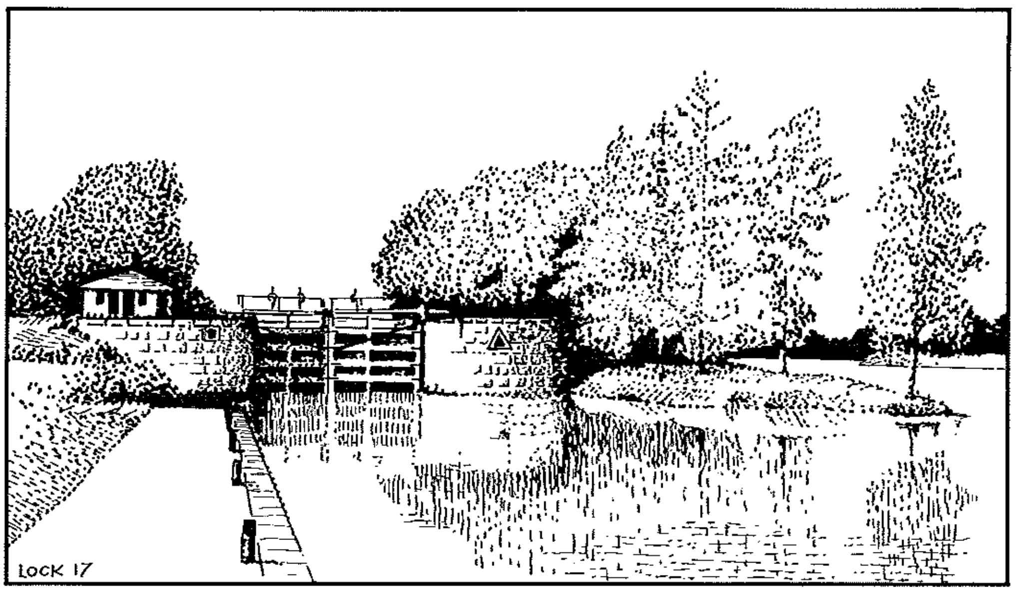
Report on
RIDEAU RIVER FLOODLINE MAPPING
(SMITHS FALLS TO KARS)

for the
RIDEAU VALLEY
CONSERVATION AUTHORITY



June 1976

JAMES F. MacLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS AND SCIENTISTS

JAMES F. MacLAREN LIMITED
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435 McNicoll Ave., Willowdale, Ontario M2H 2R8 (416) 499-0880

Ref: 10465-0

August 27, 1976

The Chairman and Members,
Rideau Valley Conservation Authority,
Box 599,
Mill Street,
Manotick, Ontario.

Re: Rideau River Floodline Mapping (Smiths Falls to Kars

Dear Sirs,

By means of an engineering agreement dated August 12, 1975, our firm was authorized to undertake a flood plain mapping study of the Rideau River from Smiths Falls to Kars.

The floodline mapping and determination of fill lines have now been completed. The results of our studies are presented in the enclosed report and detailed technical considerations are documented in the attached Appendix entitled, "Technical Discussion".

We would like to express our sincere appreciation to all appropriate members of the Authority staff and the Ministry of Natural Resources for their cooperation and assistance throughout the course of this study. All of which is respectfully submitted.

Yours very truly,

R B Wigle

R. B. Wigle, P. Eng.
Project Manager

HS Belore

H. S. Belore, P. Eng.
Water Resources Division

RBW:mb
Encl.

REPORT ON RIDEAU RIVER

FLOODPLAIN MAPPING

(Smiths Falls to Kars)

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1.0 Introduction

Flooding problems along the Rideau River are documented in the Rideau Valley Conservation Report[1], which also describes the watershed's history and natural resources. Most recently, serious flooding has been experienced in the Ottawa area of the Rideau River watershed during the 1976 spring breakup.

The Rideau River drains an area of about 1,500 square miles at its confluence with the Ottawa River. The location of the study reach within the watershed is shown on Figure 1. The study reach from Smiths Falls to Kars has an average river gradient of 4.2 ft. per mile and a length of about 23 miles. Kemptville Creek, a major tributary which has a drainage area of 177 square miles, joins the Rideau River about 8.3 miles above Kars. Historically, peak flows have occurred as a result of spring snowmelt and in some instances due to ice jams along the river.

Previous floodplain mapping studies in the watershed have been carried out on:

a) Rideau River from Ottawa to Kars[2]
b) Kemptville Creek at Kempville[3]
c) Tay River in Perth[4]
d) Steven Creek between Kars and North Gower[5]
e) Jock River between Rideau River and Richmond[6]

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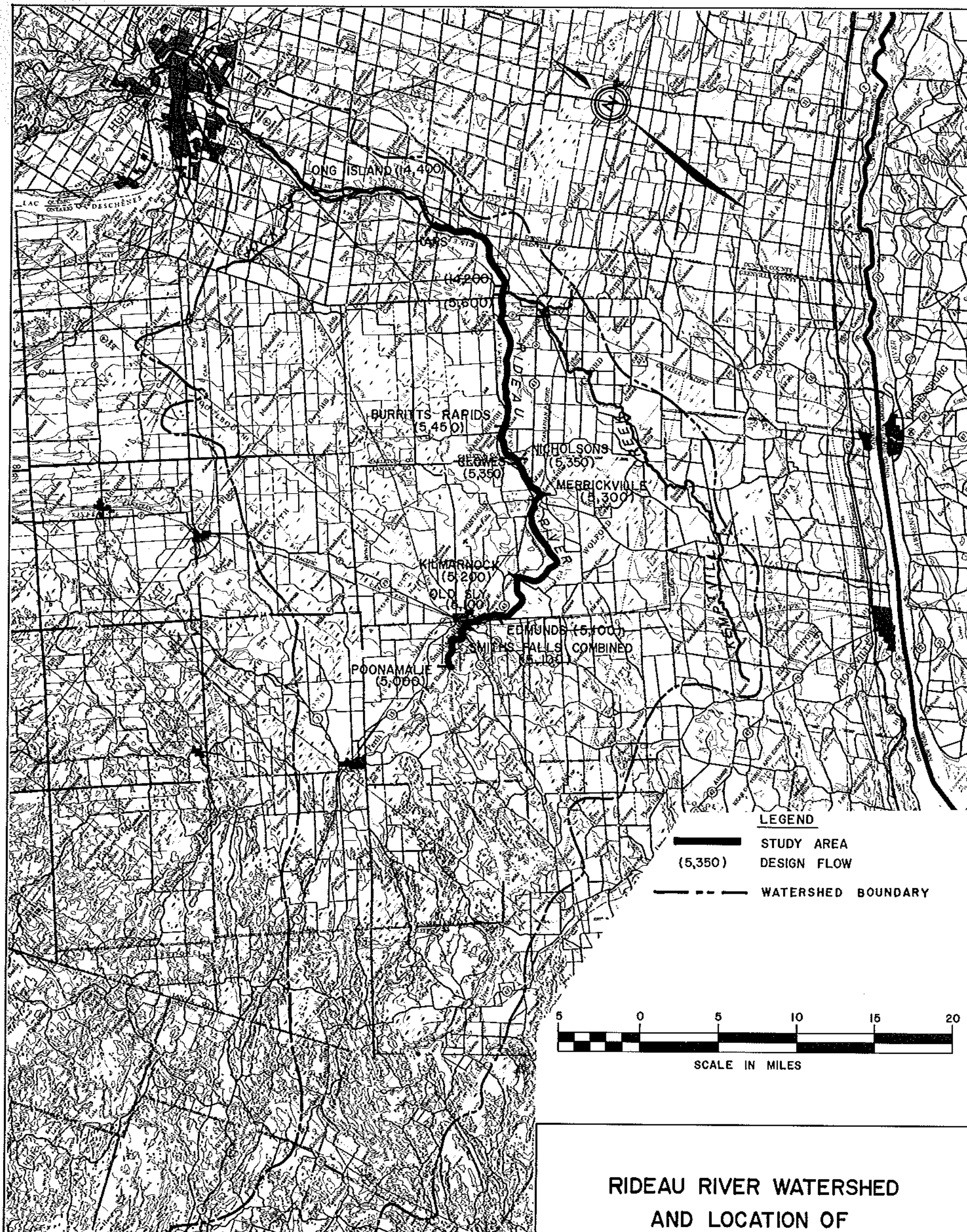
1. Rideau Valley Conservation Report, Department of Energy, Mines and Resources Management, Toronto, 1968
2. M. M. Dillon Ltd., "Rideau River Flood Plain Mapping from Ottawa to Kars", Rideau Valley Conservation Authority, July, 1971
3. James F. MacLaren Limited, "Report on Flood Plain Mapping for the Town of Kemptville", for the Rideau Valley Conservation Authority, April, 1972



RIDEAU RIVER WATERSHED AND LOCATION OF STUDY REACH

FIG. No. 1

By means of an engineering agreement dated August 12, 1975, this firm was authorized to carry out a floodplain mapping study from Kars to Smiths Falls. The major tasks to be accomplished are summarized as follows:

1. Collect and review all existing reports, hydrological/meteorological data, drawings, maps, and other pertinent data related to the work.

2. Carry out a detailed reconnaissance of the study area with particular attention to the existing structures that could affect the water levels during high flow periods such as weirs, bridges, locks, dams, etc.

3. Establish river cross sections, downstream control elevations, and design flood flows for the river and carry out backwater computations based on these data.

4. Produce controlled photomosaic sheets of the study reach at a scale of 1:5000, showing the cross section locations, flood elevations and plotted floodline and spot elevations on selected structures.

5. Prepare a draft report summarizing the findings and upon written approval of the Rideau Valley Conservation Authority submit a final report together with drawings and computer data.

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4. McCormick, Rankin & Associates Limited - Flood Plain Limits for the Tay River in Perth, November, 1971.

5. J.L. Richards & Associates Limited - Report on Flood Plain Mapping of Steven Creek between Kars and North Gower, January, 1972.

6. J.L. Richards & Associates Limited - Report on Flood Plain Mapping of Jock River between Rideau River and Richmond, December, 1972.

Subsequent to the initial study authorization, the scope of investigation was extended to include the delineation of fill lines on the photomosaic mapping.

Details of the study methodology and calculations are presented in the appended Technical Discussion. The following sections summarize the main findings of the study.

2.0 Design Flows

Extensive flow measurements were obtained from the Water Survey of Canada and from records maintained by the Rideau Canal office of Parks Canada in Smiths Falls. The Parks Canada records of water levels and flows at the various lock structures of the Rideau Canal proved to be extremely valuable in determining design flows within the study reach. A summary of the available flow records which were utilized in the study is presented in the Technical Discussion.

A frequency analysis of the available flow records was carried out to determine the peak design flow with a one in 100 year return frequency. The water levels within the study area are controlled by a number of dams and locks for the purpose of summer navigation. Therefore, the study reach was divided into segments and the design flows for each segment determined as summarized on Figure 1 and Table 1.

TABLE 1

SUMMARY OF DESIGN CONDITIONS AT CONTROL STRUCTURES

Location	Drainage Area Square Miles	1 in 100 Year Design Flow (CUSECS)	1 in 100 Year Design Water Level (Feet)
Kars	1098	14,300 405	286.3
Burritts Rapids Dam	793	5,450	292.8
Nicholsons Dam	751	5,350	307.5
Clowes Dam	751	5,350	314.6
Merrickville Dam	733	5,300	339.9
Kilmarnock Dam	617	5,150	341.9
Edmunds Dam	589	5,100	350.3
Old Sly Dam	537	5,050	365.9

DA @ Kars 1098 mi^2 = 2846 km^2 vs 2987 km^2 ([illegible] / [illegible] Robinson)

3.0 Flood Levels

The physical dimensions of the control structures together with the operational mode during design flow conditions were used to determine the design headwater levels at each structure. It was possible to compare these levels which were based on hydraulic computations with the maximum water elevations recorded at the upper sill of each lock structure for the period 1879-1975. The measured and computed levels were in close agreement; therefore, the computed levels presented in Table 1 are considered representative during the 100 year event and were adopted for purposes of this study. The normal operation of the control structures during the navigation season is not expected to produce higher water levels than the values employed for flood plain mapping.

The headwater elevations were subsequently used to initiate backwater calculations and establish design flood levels for each reach between control structures. Photographic river cross-sections developed by Kenting Earth Sciences Limited at intervals of 1000 feet along the river were used in conjunction with information obtained from the Canadian Hydrographic Service to define the shape of the channel. A field investigation was carried out to augment the existing information on river characteristics and bridge dimensions. The profile resulting from the backwater computations for the 1 in 100 year flood is shown on Figure 2, and the floodline is plotted on the photomosaic sheets which accompany this report.

4.0 Fill Lines

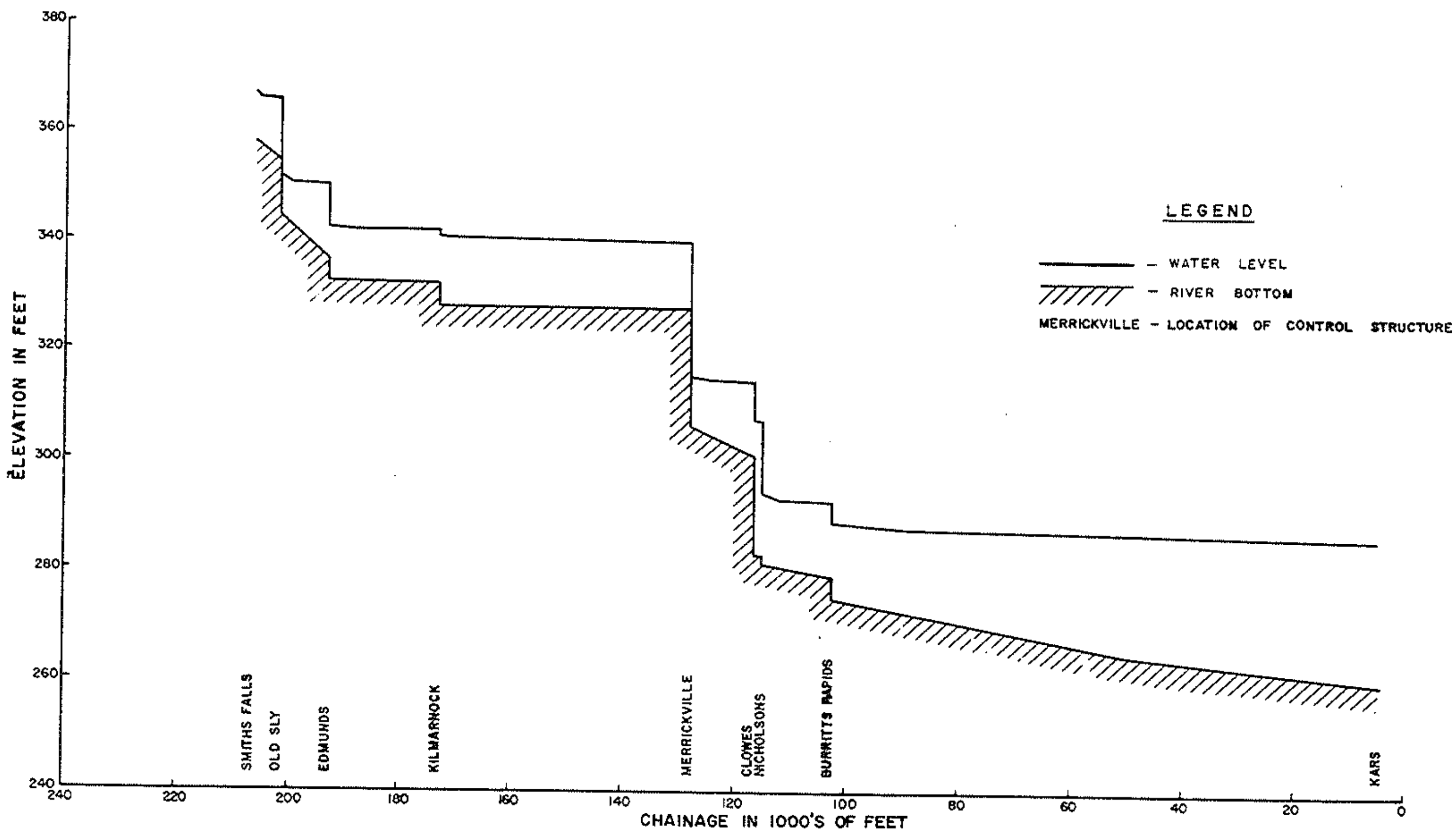
Fill and construction limits, as presented on the accompanying photomosaic drawings identify areas in which special consideration is required before proceeding with development or the dumping of fill. Slope erosion and flood susceptibility were adopted as the prime environmental hazards which preclude unregulated development; subsequently, the fill lines were positioned by stereoscopic interpretation of aerial photographs and verified during the field survey. The criteria, upon which the fill and construction lines were established, are given under the following hazard classifications:-

1. Slope Erosion

   In those instances in which the river valley walls exhibit a susceptibility to erosion and potential instability, the fill lines are located at the limit of potential erosion.

2. Flood Susceptibility

   For those reaches in which erosion potential is not a prime factor, the reservation of sufficient open space to permit the passage of the 100 year flood is considered a reasonable objective. In order to prevent the inundation of developed areas by flood waters, the fill lines in these areas are positioned at a distance of fifty feet from the 100 year floodline.



1/100 YEAR FLOOD LEVEL PROFILE
KARS TO SMITHS FALLS

FIG. 2

5.0 Flood Hazard Areas

The channel capacity of the Rideau River between Kemptville Creek and Smiths Falls is sufficient to convey the design flow with minimal overbank flooding. However, the control structures at Nicholsons and Old Sly locks cannot safely pass the total discharge under these severe flood conditions. Flows in excess of 4800 cfs and 3850 cfs at the two structures respectively are bypassed via the adjoining locks thereby limiting the maximum upstream water levels. The flood stage at these locations is normally slow in rising, thus providing Parks Canada personnel adequate warning to open the locks and to pass the excess flow. In calculating the upstream water levels, continued operation of the control structures in this manner was assumed.

The floodplain downstream of the confluence of Kemptville Creek with the Rideau River is broader in extent and is intersected by several streams including Steven Creek, Cranberry Creek and McDermot Drain. The major portion of the flow is conveyed by the existing channel; however, it is possible that some basement flooding could be experienced due to shallow floodwater depths of 1 to 1.5 feet on the floodplain fringe. In such cases, due to the shallow depth and relatively low flow velocities which could be expected, it is suggested that floodproofing of individual structures should be considered.

APPENDIX

TECHNICAL DISCUSSION TO ACCOMPANY THE REPORT ON RIDEAU RIVER FLOODLINE MAPPING

SMITHS FALLS TO KARS

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1. HYDROLOGY

1.1 General

Historically, peak flows in the Rideau watershed have occurred as the result of spring snowmelt. Records of maximum daily flows are available at various locations, as summarized in Table TD1.

1.2 Generation of Design Flows

When adequate flow records are available, the design events can be defined by the use of frequency analyses. The available peak flow data at various locations were plotted on log-probability paper using the following plotting position formula: [1]

$$P = \frac{M}{N+1} \tag{1}$$

where: M is the rank (largest to smallest)
N is the sample size.

The lognormal probability distribution was then obtained using the generalized linear frequency function: [2]

$$X\ (T,N) = \overline{X} + K\ (T,N)\ S \tag{2}$$

where: X = observed value of the variate with a recurrence interval of T years, in a sample size of N.

TABLE TD1

SUMMARY OF AVAILABLE FLOW RECORDS

Location	Drainage Area Square Mile	Source	Period
Rideau River at Ottawa (02LA004)	1480	Water Survey of Canada	1966 - '75
Rideau River at Ottawa (02LA002)	1490	"	1933 - '66
Rideau River at Ottawa	1490	M. M. Dillon Ltd. Report [10]	1916 - '44
Tay River near Glen Tay (02LA001)	204	Water Survey of Canada	1915 - '26
Kemptville Creek near Kemptville (02LA006)	158	"	1969 - '75
Jock River near Richmond (02LA007)	216	"	1969 - '75
Rideau River above Smiths Falls (02LA005)	497	"	1970 - '75
Rideau River at Long Island	1149	Rideau Canal office, Smiths Falls	1949 - '75
Rideau River at Merrickville	733	"	1942 - '75
Rideau River at Poonamalie	497	"	1944 - '75

$\overline{X}$ = mean value of N values of X

K = Frequency value, for the Lognormal probability distribution function, with a recurrence interval of T years in a sample size of N.

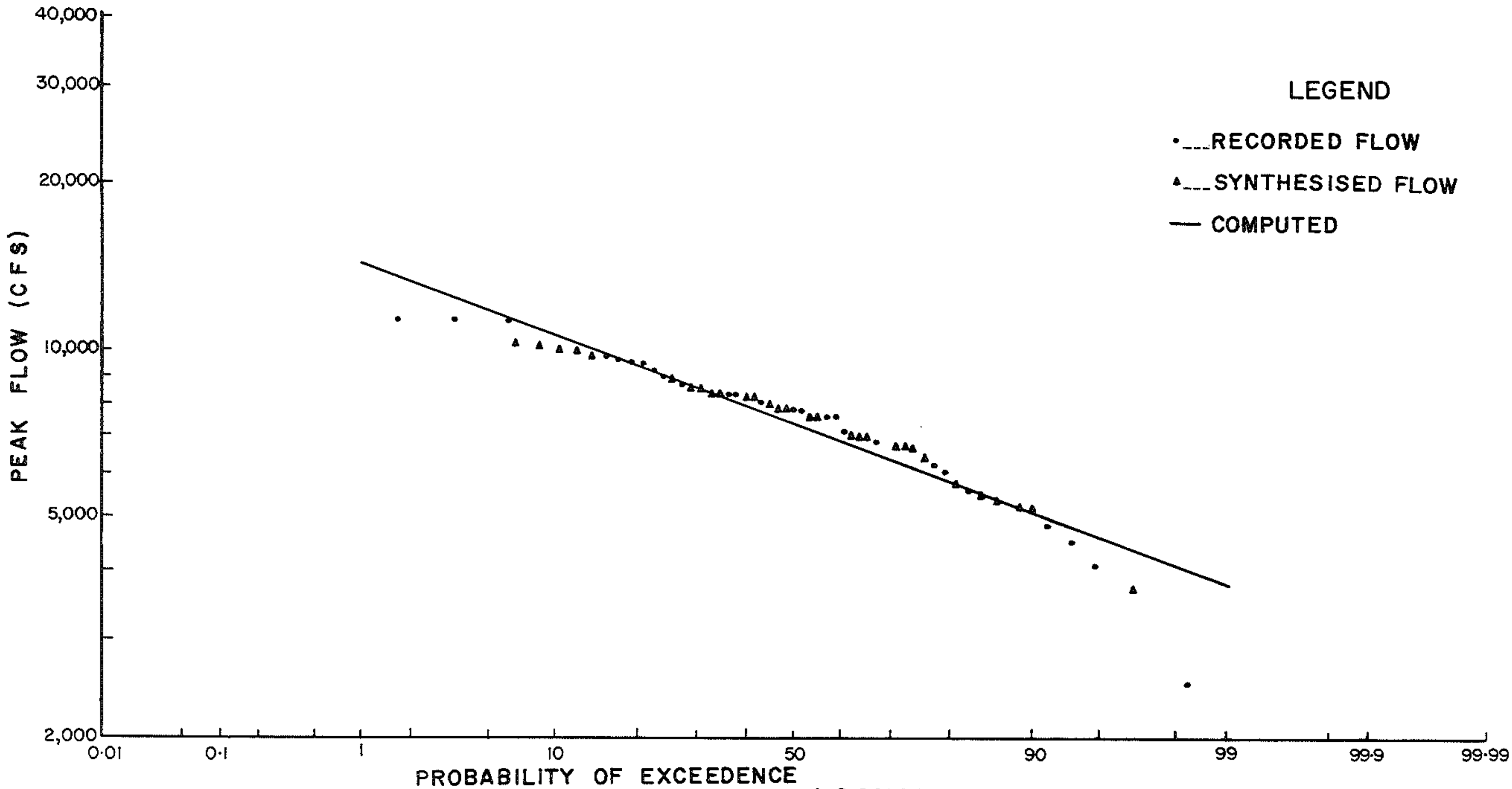
S = Standard deviation of N values of X.

The flow records of Rideau River at Ottawa were available from 1916 to date whereas at Long Island, Merrickville and Poonamalie the records date from 1949, 1942 and 1944 respectively. The recorded flow at Long Island, Merrickville and Poonamalie were correlated with those available at the Ottawa gauge in order to extend the period of record at the former 3 stations. Effectively, the method results in a change in plotting position of the measured data.

Records gathered during major floods on the Rideau River have confirmed that peak instantaneous discharges and peak mean daily flows are quite similar. Therefore, in view of the large conveyance capacity of the River, the peak mean daily 100 year flow was adopted for flood plain mapping purposes. The resulting frequency plots for peak daily flows at Long Island, Merrickville and Poonamalie are shown in Figures TD1, TD2, and TD3 respectively. The 1 in 100 year flood at recording stations along the river are indicated in Table TD2.

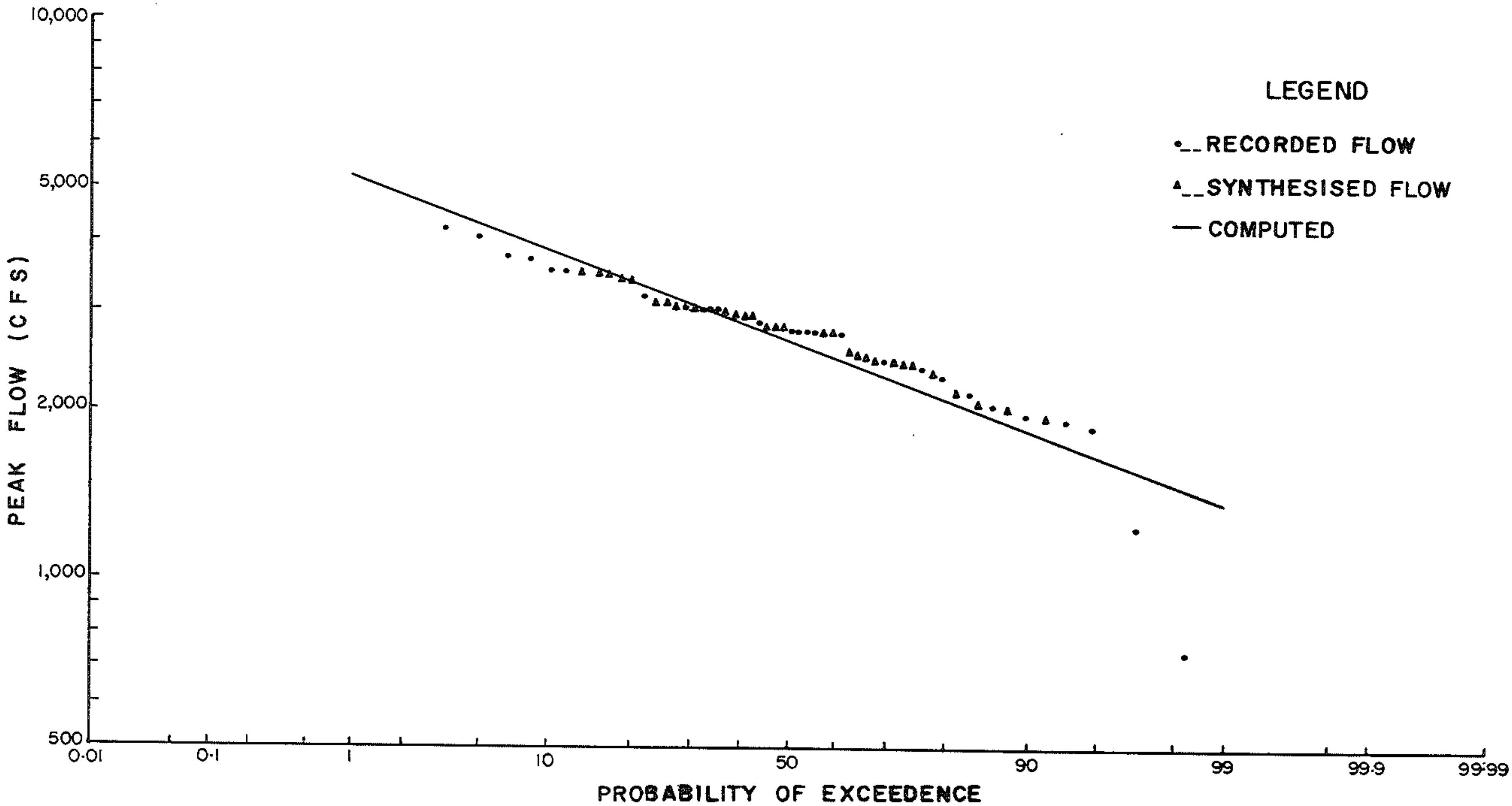
1.3 Distribution of Design Flow to Study Segments

For purposes of floodline calculations, estimates of the design flood discharge are required at all regulation structures and intermediate river reaches. Between Smiths



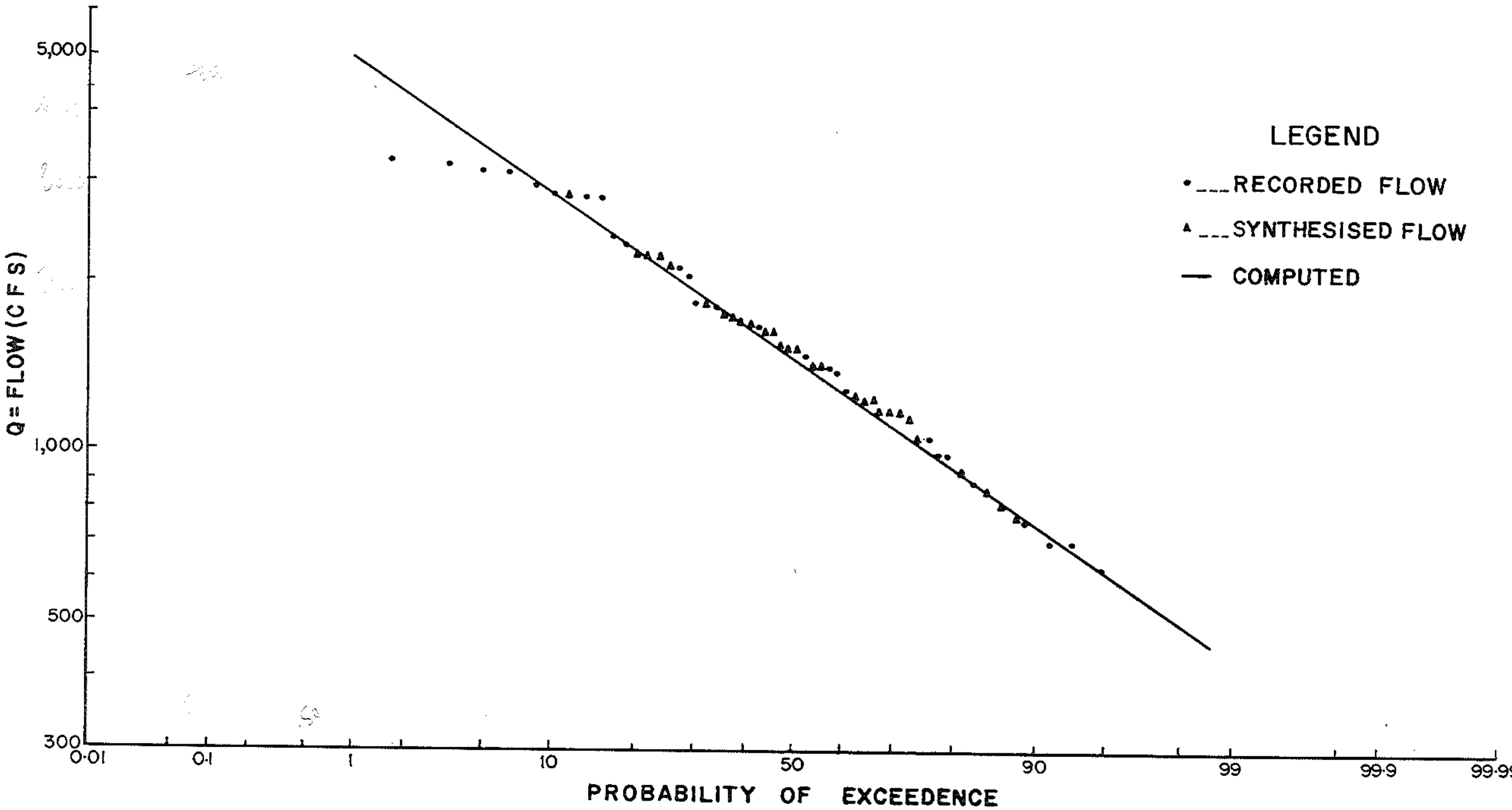
LOGNORMAL FREQUENCY ANALYSIS OF PEAK FLOW AT LONG ISLAND PERIOD OF RECORD 1916-75

FIG. T.D. 1



LOGNORMAL FREQUENCY ANALYSIS OF
PEAK FLOW AT MERRICKVILLE
PERIOD OF RECORD 1916-75

FIG. T.D. 2



LOGNORMAL FREQUENCY ANALYSIS
AT POONAMALIE

FIG. T.D. 3

TABLE TD2

SUMMARY OF DESIGN FLOW

AT RECORDING STATIONS

Station	1 In 100 Year Design Flow (CUSECS)
Long Island	14,400
Merrickville	5,300
Poonamalie	5,000

Falls and Kars seven control dams regulate water levels for the purpose of summer navigation. Accordingly, the design flows at these locations between the three flow recording stations (Merrickville, Poonamalie and Long Island) were obtained by a linear interpolation of discharge based upon tributary drainage areas.

Flow records on the Kemptville Creek permitted a more rigorous appraisal of the discharge to the Rideau River from this major drainage basin. An examination of hydrographs measured at Long Island, Kemptville and Merrickville indicated that for practical purposes, the peak flows on the Rideau River and Kemptville Creek coincide with respect to time. For this reason, a peak mean daily 100 year flow of 8600 cfs [10] was adopted for Kemptville Creek and added directly to the peak flow in the River at the confluence of the two waterways.

Table TD3 summarizes the design flows determined at the control structures in the study reach.

TABLE TD3

SUMMARY OF DESIGN FLOWS AT CONTROL STATIONS

Location	Drainage Area Square Miles	1 in 100 Year Flow (CUSECS)
Kars	1098	14,300
Downstream of Kemptville Creek	1048	14,200
Upstream of Kemptville Creek	871	5,600
Burritts Rapids	793	5,450
Nicholsons	751	5,350
Clowes	751	5,350
Merrickville	733	5,300
Kilmarnock	617	5,150
Edmunds	589	5,100
Old Sly	537	5,050
Smiths Falls	522	5,050

2.0 FLOOD LEVELS

2.1 Design Water Levels At Control Structures

Design water levels upstream of control structures are a function of the following factors:

a) Design Flow
b) Operational Mode
c) Physical Dimensions of the Control Structure

Pertinent physical characteristics of the control structures which were obtained from the Rideau Canal Office, Smiths Falls and supplemented during the field survey, are presented in Table TD4. Both structural details and operation have remained essentially unchanged since the seven locks and control dams were constructed within the study reach. During peak spring runoff periods, water levels are regulated by adjusting the number of stop-logs at each control structure in accordance with an established operational procedure. The operation rules are summarized in Table TD5. The flow capacity at all control structures within the study reach is sufficient to pass the design flows with the exception of Old Sly and Nicholsons which have flow capacities of 4800 cfs and 3850 cfs respectively. Under severe conditions, flooding would occur at these two locations with the possibility of damage to the structures. Maximum upstream water levels are therefore limited to the bottom chord elevation of adjacent bridge crossings and excess River flows are by-passed directly through the lock structures.

With the exception of the above noted structures, the design headwater elevation at each control dam was computed by the weir formulae indicated on Table TD4; these formulae are recommended by Parks Canada personnel based on their operating experience. Table TD6 summarizes the design flows and headwater levels for each river segment.

2.1.1 Comparison of Recorded Water Levels with Computed Headwater Levels

The Rideau Canal offices at Smiths Falls maintain a complete record of daily water levels of upper and lower sills at all locks along the study reach. The available water level data reviewed during this study dates back to the year 1879. Lock structures have remained essentially unchanged since that time. A summary comparison of computed and recorded water levels presented in Table TD7, indicates that the recorded maximum upper sill water levels and the computed 100 year levels are in close agreement.

2.2 Backwater Model

2.2.1 General

The RBACK computer program developed by James F. MacLaren Limited was used to compute backwater profiles. The model in its simplest form consists of three parts which each perform a specific task:

a) Backwater in River Channels
b) Backwater Thru Bridges and Weirs
c) Option of Plotting X-Sections

a) Backwater in River Channels

The longitudinal profile irrespective of flow classification is determined by the standard step method as applied to nonprismatic River Channels. An iterative technique was utilized to equalize two equations:

TABLE TD4

SUMMARY OF PHYSICAL DIMENSIONS OF CONTROL STRUCTURES **

Location	Flow Capacity CUSCES	Length of Bay ft.	Dam Crest GSD ft.	WEIR 1 1 No. of Logs -	WEIR 1 2 Clear Width ft.	WEIR 1 3 Height of Logs inch	WEIR 1 4 Sill GSD ft.	WEIR 2 1	WEIR 2 2	WEIR 2 3	WEIR 2 4	WEIR 3 1	WEIR 3 2	WEIR 3 3	WEIR 3 4	WEIR 4 1	WEIR 4 2	WEIR 4 3	WEIR 4 4	WEIR 5 1	WEIR 5 2	WEIR 5 3	WEIR 5 4
Burritts Rapids	8,600	192	291	10	24	12	282.02	11	20	12	282.25												
Nicholsons	3,850	175	305.8	7	22.7	12	297.76																
Clowes	8,300	305*	312.44*	8	29.3	13	304.35																
Merrickville	18,950			15	22	15	319.47	15	22	15	319.45	16	20	15	318.46								
Kilmarnock	7,000			5	20	12	334.46	5	20	12	334.31	5	20	12	334.4	5	20	12	334.35	5	20	12	334.42
Edmund	5,700	315	348.86	10	25	12	338.80																
Old Sly	4,800			7	20	12	357.60	7	20	12	357.6	7	20	12	357.6								

* Stage- discharge rating used, Q = 2.95 b H 3/2

Other cases --------------- , Q = 3.33 b H 3/2

Where Q = discharge in cusecs

b = weir width of dam crest or weir sill

H = head on crest or weir sill

** See reference 3 for description of control structures and weirs

TABLE TD5

OPERATION OF CONTROL STRUCTURES

DURING PEAK SPRING RUNOFF

Control Structure	Number of Logs Remaining in Dam Weir #1	Weir #2	Weir #3	Weir #4	Weir #5
Smith Falls Detached	0	0	0	0	0
Smiths Falls Combined	0	0	0	-	-
Old Slys	0	0	0	-	-
Edmunds	0	-	-	-	-
Kilmarnock	0	0	0	0	0
Merrickville	6	6	12	-	-
Clowes	2	-	-	-	-
Nicholsons	0	-	-	-	-
Burritts Rapids	2	2	-	-	-

TABLE TD6

BACKWATER SEGMENTS WITH DESIGN FLOWS AND INITIAL WATER LEVEL

Backwater Block	Design Flow (CUSECS)		DESIGN WATER LEVEL AT CONTROL STATIONS: Starting Water Level at Downstream End (ft)	Remarks
I				
Kars - Burritts Rapids	Kars	14,300	286.3	M.M. Dillon Limited Study (Ottawa - Kars)
	Downstream of Kemptville Creek	14,200		
	Upstream of Kemptville Creek	5,600		
	Burritts Rapids	5,450		
II				
Burritts Rapids - Nicholsons	Burritts Rapids Nicholsons	5,450 5,350	292.8	Computed from physical dimension of controlling dam.
III				
Nicholsons - Clowes	Nicholsons Clowes	5,350 5,350	307.5	Bottom chord of bridge deck at the top of controlling dam
IV				
Clowes - Merrickville	Clowes Merrickville	5,350 5,300	314.6	Computed from physical dimension of controlling dam
V				
Merrickville - Kilmarnock	Merrickville Kilmarnock	5,300 5,150	339.9	"
VI				
Kilmarnock - Edmunds	Kilmarnock Edmunds	5,150 5,100	341.9	"
VII				
Edmunds - Old Sly	Edmunds Old Sly	5,100 5,050	350.3	"
VIII				
Old Sly - Smiths Falls	Old Sly Smiths Falls	5,050 5,050	365.9	Bottom chord of bridge deck at the top of controlling dam.

TABLE TD7

COMPARISON OF COMPUTED DESIGN LEVELS AND HISTORICALLY RECORDED MAXIMUM LEVELS

Location	Recorded Maximum Water Level At: Upper Sill GSD (ft.)	Lower Sill GSD (ft.)	Computed 1/100 Year Design Level GSD (ft.)
Burritts Rapids	293.2	287	292.8
Nicholsons	307.1	293	307.5
Clowes	*	*	314.6
Merrickville	339.9	315.5	339.9
Kilmarnock	341.9	341.0	341.9
Edmund	350.1	341.7	350.3
Old Sly	367.3	349.9	365.9

* No water levels recorded.

$$H_2 = Y_2 + Z_2 + \frac{V_2^2}{2g} \quad (3)$$

$$H_2 = H_1 + 1/2 \Delta X (Sf_1 + Sf_2) \quad (4)$$

Where, H_1 = Energy level at a downstream section

$Z_2 + Y_2$ = Water level at an upstream section

H_2 = Energy level at an upstream section

V_2 = Velocity of flow thru upstream section

Δx = Step length

Sf_1, Sf_2 = friction slopes at downstream and upstream sections defined by Manning's equation.

The program has the capability of interposing intermediate sections within a step. This ensures rapid and exact convergence of the numerical solution.

b) Backwater Thru Bridges & Weirs

With known hydraulic parameters at downstream X-Sections, the program treats bridge details and upstream X-Sections simultaneously. Losses through bridges and weirs and subsequent solution of hydraulic parameters in the upstream X-Section is performed in a manner recommended by U.S. Department of Transportation in their Design Series "Hydraulics of Bridge Waterway".

c) Option of Plotting X-Section

The program has the capability of plotting natural river X-Sections. The computer output to accompany the report includes a plot of each X-Section used in the Backwater Model.

The study-reach was defined by X-Sections located at intervals of about 1,000 ft. centre to centre. Photographic X-Sections developed by Kenting Earth Sciences Limited were used in conjunction with information provided by the Canadian Hydrographic Service to define the shape of the river bottom. These cross-sections were then input to the backwater model. The bridge dimensions along the study-reach were surveyed in the field to supplement the information available on bridge drawings collected from the various agencies indicated in bibliography.

2.2.2 Manning's "n"

The available records along the study-reach indicate that the water level is primarily determined by the control structure operation at the downstream end of each segment. A Mannings "n" value of .035 was determined from an appreciation of the river characteristics as obtained during the field survey. Initial backwater computations verified that the starting water level is the single most important factor for the backwater calculations in each study-reach. In most cases, the water levels upstream of the control structures form a level pool.

2.2.3 Flood Levels for the 1 in 100 Year Flow

The profile resulting from the backwater computations for the 1 in 100 year flood is shown on Figure 2 of the report. An original copy of computer input and output defining all hydraulic parameters and computation of flood levels for design flows is available as documentation of all calculations. A computer input deck is also available as a data bank for future calculations as required.

3.0 LIST OF REFERENCES

1. L.R. Beard, "Statistical Methods in Hydrology" revised edition published under civil works investigations project CW-151 by the U.S. Army Engineer District, Corps of Engineering, Sacramento, California, January, 1962.

2. G.W. Kite, "Flood Frequency and Risk" Inland Waters Directorate, Water Resources Branch, Ottawa, Canada 1974.

3. Parks Canada, "Stage-Discharge Curve of Control Structure in Rideau River", Rideau Canal office, Smiths Falls.

4. U.S. Department of Transportation, "Hydraulics of Bridge Waterways", Federal Highway Administration, Washington, D.C. 1970.

5. Canadian Hydrographic Service, "Rideau Waterway Hydrographic Chart - Smiths Falls to Kars (field sheets)", Marine Sciences Directorate, Department of the Environment, Ottawa.

6. Structural details collected from following agencies in the form of maps and plans:

   a) Ministry of Transportation & Communication, Ontario,

   b) Regional Municipality of Ottawa-Carleton

   c) Canadian National Railways

   d) Canadian Pacific Railways

7. V. T. Chow, "Open Channel Hydraulics", McGraw-Hill, 1959

8. Rideau Valley Conservation Report, Department of Energy & Resources Management, Toronto, 1968.

9. James F. MacLaren Limited, "Report on Flood Plain Mapping for the Town of Kemptville for the Rideau Valley Conservation Authority", April, 1972.

10. M. M. Dillon Limited, "Rideau River Flood Plain Mapping - Ottawa River to Kars", Rideau Valley Conservation Authority, July, 1972.